U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 106.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE LIFE HISTORY AND BIONOMICS OF SOME NORTH AMERICAN TICKS.

BY

W. A. HOOKER, F. C. BISHOPP, AND H. P. WOOD.

UNDER THE DIRECTION OF

W. D. HUNTER.

ISSUED SEPTEMBER 7, 1912.

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BUREAU OF ENTOMOLOGY.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., November 29, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "The Life History and Bionomics of Some North American Ticks," prepared by Messrs. W. A. Hooker, F. C. Bishopp, and H. P. Wood, under the direction of Mr. W. D. Hunter, of this bureau. Ticks are of considerable importance in the United States in two respects. Two species are the sole agents in the transmission of certain important diseases. One of these diseases is the well-known splenetic fever of cattle and the other the Rocky Mountain spotted fever of human beings. The information contained in this manuscript will be of immediate value in connection with the eradication of the cattle tick and also of the form which transmits spotted fever. The remaining species treated in this manuscript are now of importance principally as parasites of domestic animals. In many localities they present serious problems to the farmer. Moreover, there is a possibility that some of the species not known at present to be carriers of diseases will eventually be found to be of importance in connection with disease transmission. For these reasons full information regarding the life history of the various species is in demand.

The work upon which this bulletin is based has extended from 1907 to the present time. The manuscript is intended to be a compendium of information regarding ticks which will remain of direct value for many years and make unnecessary the publication of special bulletins on some of the species treated.

I recommend that this manuscript be published as Bulletin No. 106 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE LIFE HISTORY AND BIONOMICS OF SOME NORTH AMERICAN TICKS.

INTRODUCTION.

During the course of investigations of the biology of the North American fever or cattle tick, conducted by the Bureau of Entomology, with headquarters at the field laboratory at Dallas, Tex., many other species of ticks were met with, some of which are of considerable economic importance. In view of their importance as ectoparasites and the part that several are known to play in the transmission of disease, and in view of the further fact that comparatively little was known of their life history and bionomics, it was decided that the investigations should be extended to include as many of the species as possible.

During 1905 a few notes were made upon ticks other than the cattle tick (*Margaropus annulatus*), which was at that time being studied. These miscellaneous notes were consolidated with those of 1906 during the winter of 1906–7 and published in Bulletin 72 of this bureau, together with the results of studies of the cattle tick. In 1907 further attention was given to those species which could be obtained for study. During the summer of that year valuable information was received from Prof. C. P. Lounsbury, who visited the laboratory. In 1908 the study of various species was taken up more extensively. The work was confined principally, however, to those species occurring in Texas. In 1910 an investigation of the Rocky Mountain spotted-fever tick (*Dermacentor venustus*) was undertaken by the bureau in cooperation with the Montana Agricultural Experiment Station and the Bureau of Biological Survey. Incidental to the work on the spotted-fever tick studies were undertaken on the life histories and habits of a number of species of ticks occurring in the western United States, and several species not herein discussed are at the present time being studied. Our knowledge of the life his-

tories of some of these species is rather complete, but it seems desirable to withhold from publication the results of investigations of these species until further data are accumulated.

This tick investigation has been conducted, throughout, under the general direction of Mr. W. D. Hunter, from whom the writers have received many helpful suggestions. Mr. W. A. Hooker had direct charge of the investigation from its inception until September 15, 1908, when Mr. F. C. Bishopp took direct charge of the investigation and has carried it forward. Mr. H. P. Wood's connection with the work has been continuous since November, 1907. Mr. J. D. Mitchell and Mr. F. C. Pratt (now deceased) contributed valuable assistance by collecting material and making notes on host relations and economic status. Mr. W. V. King, acting under the direct supervision of Prof. R. A. Cooley, of the Montana Agricultural Experiment Station, has, by the collection of several hundred lots of ticks in the Northwestern States, supplied a large amount of information on the hosts of *Dermacentor venustus* and other species and some information upon the geographical distribution of these species. Prof. Cooley has also aided materially in several ways, including the sending of a number of specimens of *Ixodes kingi*, which were used in the studies of that species published herein. Several correspondents, particularly in the Western States, have furnished a large number of lots of ticks which have been of much value in the work. Mr. C. E. Hood, Mr. G. N. Wolcott, and Mr. G. W. Hood are responsible for a few of the counts of eggs, and these gentlemen, as well as Mr. E. A. McGregor and Mr. J. Jacobs, have assisted in the summarization and tabulation of records.[1]

CONCERNING TICKS IN GENERAL.

SYSTEMATIC POSITION AND CLASSIFICATION.

The ticks form a superfamily of the order Acarina, and are closely related to the mites which produce scab, mange, and itch. The superfamily Ixodoidea, to which all the ticks belong, is composed of two families, namely, the Argasidæ, represented in this country by 2

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[1] Credit for taking the photographs used in making the plates in this bulletin should be given as follows:
H. P. Wood: Plate I, fig. 1.
F. C. Bishopp: Plate I, fig. 6; Plate III, fig. 2; Plate XIV, fig. 5.
W. E. Hinds: Plate II, fig. 1; Plate VI, fig. 10; Plate VII, figs. 1, 5, 6; Plate VIII, fig. 5; Plate XI, fig. 3; Plate XIII, fig. 14.
W. A. Hooker: Plate I, figs. 4, 5; Plate III, figs. 1, 3, 4; Plate V, figs. 1, 4; Plate VI, figs. 11, 12, 15; Plate VII, figs. 2, 4; Plate VIII, figs. 1, 2; Plate IX, figs. 1–8; Plate X, figs. 1–10; Plate XI, figs. 1, 4, 5, 7, 8, 9; Plate XII, figs. 1, 4, 7; Plate XIII, figs. 1–13; Plate XIV, fig. 2; Plate XV, figs. 1–4, 10, 11.
G. N. Wolcott: Plate I, figs. 2, 3; Plate II, fig. 2; Plate III, figs. 5–8; Plate IV, figs. 1, 9; Plate V, figs. 2, 3, 5–8; Plate VI, figs. 1–9, 13, 14, 16, 17; Plate VII, figs. 3, 7–10; Plate VIII, figs. 3, 4, 7–11; Plate XI, figs. 6, 10; Plate XII, figs. 2, 3, 5, 6, 8–12; Plate XIV, figs. 1, 3, 4, 6–9; Plate XV, figs. 5–9.

genera and 6 (possibly 7) species, and the Ixodidæ, represented by 8 genera, 36 species, and 3 varieties, as follows:

- Ixodoidea...
  - Argasidæ .
    - Argas (2 species in the United States).
    - Ornithodoros (4 species in the United States).
  - Ixodidæ ..
    - Rhipicephalinæ
      - Rhipicephalus (1 species in the United States).
      - Margaropus (1 species in the United States).
      - Hæmaphysalis (2 species in the United States).
      - Dermacentor (8 species and 1 variety in the United States).
    - Ixodinæ ....
      - Ixodes (16 species and 2 varieties in the United States).
      - Ceratixodes (2 species in the United States).
      - Aponomma (1 species in the United States).
      - Amblyomma (5 species in the United States).

The type locality of 12 of the recognized species occurring in this country is outside of the United States. Of these 12 species 2 were described by Linnæus (1758), 2 by Fabricius (1794), 1 by Leach (1815), 3 by Koch (1844), 1 by Guérin (1849), 1 by Cambridge (1876), and 2 by Dugés (1883).

Many of the names of supposedly new species have proved to be synonyms. Nymphs have occasionally been described as new species. The sexual dimorphism and the variation in the amount of blood engorged at the time the specimens were collected account for many of the synonyms. Of the 8 species described by Say in 1821 all but 3 are synonyms or remain unrecognized, while of the 5 described by Fitch (1872) all are synonyms or remain unrecognized. Of the 9 described by Packard (1868, 1869, 1872) 5 are recognized as distinct species.

The first work upon the classification of the ticks of this country was that of Dr. Marx (1893), whose studies were soon after terminated by his death.

In 1896 Dr. L. G. Neumann published the first part of his revision of the Ixodoidea of the world, the last part of which appeared in 1901, but which has been followed from year to year by a series of "Notes." Unfortunately this valuable work, in its original form, is accessible to only a few. However, a concise summary has recently been published (1911).

The first great step in the classification of the ticks of this country was taken in 1901, when the important work by Drs. Salmon and Stiles, on the cattle ticks of the United States, was published. With the appearance, in 1908, of the revision of the Ixodoidea of the United

States,[1] by Mr. Nathan Banks, a work became available by means of which most of the ticks of this country can be readily identified. Since this work appeared several new species have been described by Messrs. Banks (1910), Stiles (1910), and Bishopp (1911b),[2] so that at present 42 species and 3 varieties representing the genera Argas, Ornithodoros, Amblyomma, Aponomma, Ceratixodes, Dermacentor, Hæmaphysalis, Ixodes, Margaropus, and Rhipicephalus, are known to occur within our borders. A valuable monograph of the Ixodoidea is being published by Nuttall, Warburton, Cooper, and Robinson. Two parts, dealing with the Argasidae, the classification of ticks, and the genus Ixodes, have been issued.

A detailed illustrated account of the general structure of ticks, to which reference should be made, has been given by Salmon and Stiles (1901, pp. 387–398). It may be well, however, to give a brief description of the so-called capitulum or head, bearing the palpi and the haustellum, the latter of which consists of the mandibles, mandibular sheaths, and hypostome, which are inserted into the skin of the host. The capitulum is a small subtriangular piece that articulates with the anterior margin and usually within a slight emargination of the corneous shield, or scutum, which in the ixodid female forms the front part of the dorsum and in the male covers the greater part of the body. The hypostome, or labium, which lies underneath the mandibles, is an elongated dart or spatulate structure, which is composed of 2 lateral symmetrical halves bearing many hooks or denticles directed backward, so that when embedded in the flesh it can not be forcibly withdrawn with ease. The mandibles, 2 in number, are terminated anteriorly by either 2 or 3 processes, known as apophyses, that are used for piercing the flesh and making an entrance. The mandibular sheaths surround the base of the mandibles and extend backward on the dorsal side of the haustellum. Upon each side of the haustellum, applied closely thereto, are the palpi, which are grooved on the inner margin.

There is considerable variation in the size of the individual ticks of a single species, among both males and females. The engorged nymphs also vary in size, the larger usually being prefemales.[3] Under the several species measurements will be found which indicate the variation. The color, especially of the immature stages, is also quite variable. In engorged larvæ and nymphs of some species there is a variation from dark brown to pink and pale gray. This is apparently

[1] For the classification of the ticks the worker is referred to Mr. Banks's Revision of the Ixodoidea (1908). Descriptions of adults, aside from their size and coloration, have been omitted in the present work, as they will be found in Mr. Banks's Revision.

[2] See Bibliographical references, p. 205.

[3] The terms "premale" and "prefemale" have been used to denote those individuals, not yet molted to adults, in which the sex can be recognized.

due to the proportionate amount of blood, lymph, and inflammatory exudate that has been engorged.

The internal anatomy of ticks has been studied by a number of investigators, among whom mention should be made of Heller (1858), Pagenstecher (1861), Williams (1905), Allen (1905), Christophers (1906), Bonnet (1907), Nordenskiöld (1908, 1909), and Samson (1909).

COLLECTING, PRESERVING, AND MOUNTING.

Owing to the fact that very few entomologists or zoologists have had experience with the systematic collection of ticks a few suggestions along this line may prove of value. The writers have found that in many instances zoologists have received and handled specimens of skins and living animals to which ticks were attached and entirely overlooked these parasites. In other cases the ticks were seen but were not preserved. The ease with which this class of parasites may be preserved should encourage zoologists to keep on the lookout for them and to collect all specimens seen.

Persons who collect specimens of ticks should record the host, point of attachment, date, and locality. All parts of the host, including the inside of the ears, should be closely examined. Upon the discovery of a female, and before removing it, the collector should search closely for the male, which may be attached near by. A pair of forceps will be found useful in removing the smaller ticks. Those with short mouthparts are readily removed without injury, but many, particularly those of the genus Ixodes, are usually so firmly attached that the body of the tick will be separated from the capitulum unless the latter is firmly grasped. Some ixodologists have recommended the application of a penetrating oil and waiting for the tick to loosen its hold, but this will seldom be found necessary.

In collecting ticks from small animals which have been shot or trapped, a supply of small cotton bags should be at hand into which the host can be placed as soon as shot and the bag firmly tied to prevent the escape of the ticks. In this way specimens may be examined at the collector's convenience and notes may be made on the habits of the ticks. If the host animal is too large to be bagged it should be examined at once over some white surface, such as white cotton cloth spread over the ground. The importance of immediate examination is emphasized, as the writers have found that larvæ of the rabbit tick and of other species with short hypostomes commence to leave the host within a very few minutes after the animal is killed. Ticks with long hypostomes, such as Ixodes, are sometimes unable to detach, and therefore remain upon the animal. In a number of

instances living and dead ticks have been found clinging to the skins of animals which have been nailed on a wall for several days.

The collection of ticks from herbage, on which they are awaiting a host, may best be done by dragging a white cloth, preferably of wool, over bushes, grass, etc. An ordinary insect beating net may also be employed. Fruitful results have been found to attend the examination of the dens of animals, nests and regular roosting places of birds, and the ground in the vicinity of resting and watering places of mammals. Pill boxes have been found to be satisfactory receptacles for the ticks when collected.

In preserving we have usually used 80 per cent alcohol or a mixture consisting of 60 parts alcohol, 1 part formalin, and 39 parts water. Adult specimens, particularly males with bright color markings, should be mounted on pins, as well as preserved in alcohol. For microscopical study specimens should be mounted in Canada balsam on slides. The contents of the body should first be teased out in hot water, through a slit made at the posterior end of the body. Specimens can then be readily cleared by boiling in a 10 per cent solution of caustic potash (KOH), care being taken that the clearing be not carried too far. The method employed by Dr. C. W. Stiles consists in soaking the specimens in from 2 to 5 per cent caustic-potash solution for periods varying from 12 to 96 hours, after which all of the soft body content is removed, and after passing the specimens through water, the alcohols, and xylol or other clearing agents, the specimens are mounted in balsam.

ECONOMIC IMPORTANCE.

Ticks are of economic importance (1) as agents in the transmission of infectious diseases, and (2) as external parasites, both of man and the lower animals. At least two distinct diseases of man and eight or more of domestic animals are known to be thus transmitted, at least 17 species of ticks being involved as carriers. Of these diseases one of man and one of cattle occur, and one of fowls is suspected to occur, in the United States, while several others would undoubtedly obtain a foothold were they once introduced.

It has been estimated by Dr. Mohler (1905) that the cattle tick alone is the source of approximately $40,000,000 annual loss in the United States. Mayer (1906) has estimated the annual loss as nearly $100,000,000.

These parasites are of considerable importance as external parasites, particularly in the Southern States, owing not only to their irritation and great drain upon stock through removal of blood, but also to their indirect effect as well. In one of Theiler's experiments (1909a) a horse that was infested with *Margaropus decoloratus* died as a result of infestation from acute anemia due to the withdrawal of blood.

Within 3 days 14 pounds, by weight, of ticks which had dropped from this horse were collected, and this amount represented only about one-half of the total number of ticks which engorged upon it. After dropping, their places of attachment furnish points at which the screw-worm fly (*Chrysomyia macellaria*) deposits its eggs, the maggots from which then readily enter the host. In the Southwestern States the appearance of equines is frequently injured by screw-worms, which gain entrance at the points in the ears where ticks had been attached, burrow, and destroy the supporting cartilage, causing the ears to lop over. This condition is commonly known as "gotched." Not the least of all is the frequent annoyance which man suffers as the result of the attachment of ticks to his body.

The ticks which molt upon the host, instead of having to wait long periods to find another, merely continue sucking blood from the same animal. As a result these ticks reproduce very rapidly and frequently become of much greater importance as external parasites than species which drop to molt. This is the case with the cattle tick. Those which drop to molt have overcome this great disadvantage by becoming more resistant to heat and cold and by having gained the power to withstand much longer periods of fasting. Certain members of the subfamily Ixodinæ, while not occurring in such great numbers on animals as in the case of species which molt on their hosts—all of which belong to the subfamily Rhipicephalinæ—are frequently of considerable importance as pests, owing to the fact that the great length of the hypostome permits deep penetration. As the result of this deep penetration by the Ixodinæ, an inflammation is produced which frequently results in suppuration. Often in the attempt to remove ticks belonging to this latter class from the body of the host, the capitulum is separated from the body of the tick and remains embedded in the host.

The periods in the life history of ticks of particular importance economically and which should be determined are: *Longevity*, or the period required for starvation while awaiting a host; *minimum parasitic period*, which is used in connection with the preoviposition and incubation periods to determine the time that tick-free areas may be used after infested cattle are turned in before the areas become infested; *maximum parasitic period*, or the period required for cleaning the host of all ticks (except males) when kept in tick-free inclosures; *preoviposition period and minimum incubation period*, used with the minimum parasitic period to determine the time that tick-free lots may be used before becoming infested; *stage or stages of imbibition of infection* and the *stage or stages in which infection is transmitted*, i. e., in the case of species involved in disease transmission.

HISTORY OF THE BIOLOGICAL STUDY OF TICKS.

The first studies made of the life history and habits of ticks were those of Dr. Cooper Curtice (1891, 1892a, b) on the cattle tick (*Margaropus annulatus*) conducted in cooperation with the Texas Agricultural Experiment Station at about the time that Drs. Smith and Kilborne were investigating the rôle of that species in the transmission of splenetic fever. From the time of these investigations by Dr. Curtice up to 1898 little attention seems to have been given to the biology of ticks other than this species, although a preliminary study was made of *Amblyomma variegatum* (*Hyalomma venustum*) in Antigua, by C. A. Barber (1894–95).

In 1898 Dixon and Spreull reported studies made of *Margaropus decoloratus* and the same year Prof. C. P. Lounsbury, the entomologist of Cape Colony, British South Africa, began his classic studies of the Ixodoidea. Since that time Lounsbury has worked out the life history and habits of a large number of South African species. During the course of these studies he has demonstrated the transmission by ticks of three distinct diseases of domestic animals and the pathogenicity of at least seven species of ticks and has determined the stages of imbibition and of inoculation of the hosts with the disease-producing organisms.

In 1898 Dalrymple, Morgan, and Dodson, of the Louisiana Agricultural Experiment Station, published a detailed account of experiments relating to the life history of the cattle tick. The information which they furnished upon the longevity of the "seed ticks" served as a basis for the feed-lot and pasture-rotation system for cleaning stock and pastures of the cattle tick. In 1899 Prof. H. A. Morgan published further information upon the life history of the cattle tick and included data upon the biology of *Amblyomma americanum*, *Dermacentor variabilis* (*electus*), and *Ixodes scapularis* (not *ricinus*).

In 1899 E. G. Wheler, in England, published an account in which he reported studies made of *Ixodes ricinus* and the same year C. J. Pound published notes on the Australian cattle tick (*Margaropus annulatus australis*). In 1903, Dr. H. Kossel and his coworkers published an account of studies of the biology of *Ixodes ricinus* in a report of investigations made in Germany in which they found it to transmit bovine piroplasmosis. During the course of his investigations of the various protozoan diseases of animals in South Africa, Dr. Arnold Theiler, veterinary bacteriologist to the Transvaal, has added much to our general knowledge of the biology of ticks. Dr. H. T. Ricketts, in connection with his investigation of Rocky Mountain spotted fever, has published information from time to time (1907, 1909a, b) upon the life history and habits of *Dermacentor venustus*. Prof. R. A. Cooley (1908, 1911) and W. D. Hunter and F. C. Bishopp (1911a, b)

have also published studies made of that species. Capt. S. R. Christophers, working in India, has studied *Rhipicephalus sanguineus* (1907) and made observations on *Ornithodoros savignyi* (1906). In South America, Dr. F. Lahille, of Argentina (1905), has studied *Margaropus annulatus australis* and Dr. C. J. Rohr, of Brazil (1909), has conducted extensive investigations on six species. Newstead reported in 1909 on studies made in Jamaica. Among others who have studied the cattle tick are Ransom (1906), Newell and Dougherty (1906), Schroeder (1907), Hunter and Hooker (1907), Cary (1908), Cotton (1908), and Graybill (1911). Many others have recorded miscellaneous observations on different species. Preliminary notes on several species were published by Hunter and Hooker in 1907, and further information has since been published by Hooker (1908, 1909a, b, c).

GEOGRAPHICAL DISTRIBUTION.

The ticks that commonly attach to the domestic animals have been widely disseminated on the hosts so that now many of them are only limited by climatic zones. Of the several meteorologic factors which control their distribution cold appears to be the most important, although excessive heat and variation in humidity are also important. Thus in America we find the tick species most abundant in the Tropical and Lower Austral zones and the least so in the Boreal Zone. Several native species, notably *Margaropus annulatus*, *Amblyomma maculatum*, and *Argas miniatus* rarely appear above the Lower Austral Zone, while *Amblyomma tuberculatum*, *A. dissimile*, *A. cajennense*, and *Dermacentor nitens* occur only in the Tropical or Gulf strips of the Lower Austral Zone. Our two species of Ceratixodes, namely, *putus* and *signatus*, apparently occur in the Boreal Zone only.

Some species remain attached to their hosts for long periods (particularly the males) and may be carried great distances. This has resulted in numerous records which must be rejected in determining the normal distribution of a species. The approximate zonal distribution of our species is shown in Table I.

TABLE I.—*The zonal distribution of North American ticks.*

	Species.	Boreal region.			Austral region.						Tropical region.
					Transition.		Upper Austral.		Lower Austral.		
		Arctic.	Hudsonian	Canadian.	Transition.	Alleghanian.	Upper Sonoran.	Carolinian.	Lower Sonoran.	Austroriparian.	Tropical.
1	Amblyomma americanum	Doubtful	Doubtful	Occurs		Occurs		Common		Abundant	Occurs.
2	Amblyomma cajennense								Common		Abundant.
3	Amblyomma dissimile										Common.
4	Amblyomma maculatum								Abundant	Abundant	Occurs.
5	Amblyomma tuberculatum								Doubtful	Common	Occurs.
6	Aponomma inornata				Occurs		Occurs		Occurs		
7	Argas brevipes						Occurs				
8	Argas miniatus						Rare		Abundant	Occurs	Common.
9	Ceratixodes putus	Occurs	Occurs								
10	Ceratixodes signatus		Occurs		Occurs						
11	Dermacentor albipictus			Occurs	Abundant	Occurs	Common				
12	Dermacentor nigrolineatus			Occurs		Occurs		Occurs	Occurs		
13	Dermacentor nitens								Common		Abundant.
14	Dermacentor occidentalis			Common	Abundant		Common		Occurs		
15	Dermacentor parumapertus						Occurs				
16	Dermacentor parumapertus marginatus						Common		Abundant		
17	Dermacentor variabilis	Doubtful	Doubtful	Occurs	Occurs	Occurs	Occurs	Common	Occurs	Abundant	
18	Dermacentor venustus		Doubtful	Common	Abundant		Common				
19	Hæmaphysalis chordeilis					Occurs			Occurs		
20	Hæmaphysalis leporis-palustris			Occurs	Common	Common	Abundant	Common	Abundant	Abundant	Occurs.
21	Ixodes angustus			Common	Common						
22	Ixodes angustus woodi								Occurs		
23	Ixodes arcticus		Occurs								
24	Ixodes banksi							Occurs			
25	Ixodes brunneus					Occurs	Occurs	Occurs	Occurs		
26	Ixodes californicus			Occurs	Common		Occurs				
27	Ixodes cookei				Occurs	Common	Common	Common	Occurs	Occurs	
28	Ixodes cookei rugosus				Common						
29	Ixodes dentatus							Rare			
30	Ixodes diversifossus				Rare		Doubtful				
31	Ixodes aequalis						Rare				
32	Ixodes hexagonus							Rare			
33	Ixodes kingi			Occurs	Common		Common		Rare		
34	Ixodes marxi				Rare	Rare					
35	Ixodes pratti								Rare		
36	Ixodes scapularis							Common	Occurs	Abundant	Rare.

37	Ixodes sculptus				Occurs.		Occurs.		Occurs.		
38	Ixodes texanus				Common.				Occurs.		
39	Margaropus annulatus				Rare		Occurs.	Occurs.	Abundant	Abundant	Occurs.
40	Margaropus annulatus australis										Abundant.
41	Ornithodoros coriaceus				Occurs.		Occurs.		Occurs.		Doubtful.
42	Ornithodoros megnini				Rare		Common.		Abundant	Rare	Doubtful.
43	Ornithodoros talaje								Occurs.		Occurs.
44	Ornithodoros turicata						Rare		Occurs.		
45	Rhipicephalus sanguineus								Abundant	Rare	Common.

GENERAL LIFE HISTORY.

Although ticks are able to survive long periods of fasting—some species much longer than others—development takes place only following a period of attachment during which the blood of some animal, either warm or cold blooded, must be taken into the body, i. e., they are obligatory parasites. Several writers have considered the possibility that ticks may subsist in part upon vegetable matter. Prof. Lounsbury, however, who has conducted extensive studies of these arachnids, states (1905) that he has no doubt that they derive nutrition exclusively from living animals despite the protracted periods that they often have to wait for hosts. They do, nevertheless, imbibe water from the rain or dew upon herbage or from the soil. One of the writers has observed ticks kept in tubes, on dry sand, to imbibe water from the moistened sand. Many untrained observers have reported that engorged ticks give birth to living young. Ricketts (1909a, p. 104) mentions this phenomenon as having been described to him concerning *Dermacentor venustus* by a number of residents of the Bitter Root Valley, Montana. While the origin of such erroneous statements can not be determined, one explanation to be offered is that of mistaking some of the Kermes for ticks. Thus *Kermes galliformis* has been sent to one of the authors by an entomological collector who supposed it to be a tick. With the Kermes was a statement to the effect that it had been found dead with young swarming from it.

DEVELOPMENT.

All ticks pass through four distinct life stages: (1) The egg, (2) the larva or seed tick (6-legged stage), (3) the nymph or yearling tick (first 8-legged stage), and (4) the adult. All the ixodid and one (or more) of the argasid ticks engorge and molt but twice before arriving at the adult stage. Two species of Ornithodoros are reported to remain inactive in the larval stage and pass the first molt before engorging blood. Some of the argasids molt twice or three times during the nymphal stage, and at least one species continues molting after becoming adult. The larvæ of *Ornithodoros talaje*, which species is now being studied, engorge, then drop and molt twice before the next engorgement. The ixodid ticks engorge but once as adults, and die following the completion of oviposition, while most of the argasid ticks engorge a number of times as adults, oviposition following each engorgement.

MOLTING.

There is wide variation in the molting habits of ticks, even among species of the same genus. Most of the ticks, both argasid and ixodid, molt while away from the host, and the habit of molting

while attached appears to be a special adaptation. One native species (*Ornithodoros megnini* Dugès) and several exotic species (*Rhipicephalus evertsi, R. bursa, Hyalomma ægyptium*) pass the first molt upon the host, but drop for the second. A few species, including *Margaropus annulatus* and its several varieties, *Dermacentor albipictus* and *Dermacentor nitens*, pass both molts upon the host. As yet none is known to drop for the first molt and to pass the second upon the host.

HABITS.

HOST RELATIONSHIP.

Several species of ticks seem to be naturally restricted to a single genus or family of hosts, such as *Hæmaphysalis leporis-palustris* and *Dermacentor parumapertus marginatus* to the Leporidæ. Others, although attaching to some hosts more or less frequently (secondary hosts), have particular hosts (primary hosts) to which they more commonly attach. From this habit have arisen many of our common tick names, such as the cattle tick, dog tick, rabbit tick, etc.

Ticks occasionally attach themselves to animals which may be termed accidental or temporary hosts. This fact is aptly illustrated by the cattle tick, large numbers of which, in the first experiments, were repeatedly placed upon dogs by the writers, but without becoming attached. Finally, however, during the summer of 1908 several ticks attached themselves to the laboratory dogs and later, on these host animals, developed to replete females. There seems to be a rather close analogy between ticks and fleas with regard to hosts. In his revision of the Siphonaptera (1904, p. 368), Baker mentions rabbit fleas as remaining on a human being for some little time, biting frequently while there, but not frequenting the human host nor his clothing or bed. To illustrate how fleas would find these temporary hosts, he mentions the possibility of a rabbit running into a badger hole, or a mouse into a mole burrow; that the eating of a mouse by an owl or the devouring of a rat by a cat would afford favorable conditions for this temporary transference of parasites. Similar instances account for many of our accidental hosts of ticks. It thus appears that larvæ of *Amblyomma tuberculatum* become attached to hawks and owls at the time their small mammal hosts are being devoured.

Experiments conducted by the writers have shown that when confined in a bag in close proximity to the scrotum of a bovine, nearly all of the ixodids will attach. As a result of these accidental or temporary attachments for some species we have large host lists, including hosts upon which the ticks could only occasionally or never reach maturity. Prof. Lounsbury has found a peculiar habit in *Hyalomma ægyptium impressum.* As a larva, it will not feed on the

large mammals, but attaches to the heads of fowls and hares, upon which the first molt is passed. Following the second molt, which takes place off the host, it attaches to almost any of the warm-blooded animals.

Mammals serve as the principal hosts of the ticks. Fowls are largely the hosts of the genera Argas and Ceratixodes, of two North American species of the genus Hæmaphysalis, and of one of Ixodes. Several species of the genera Ixodes, Amblyomma, Aponomma, and Hyalomma are also occasionally parasitic upon fowls, and in the immature stages a number of others may attach to fowls. A large number of species have been collected from reptiles, several from amphibians, and two from beetles.

ADAPTATIONS.

Natural selection appears to have resulted in special adaptations both of function and structure and of the habits of ticks. All ticks must find hosts and attach at least once, some as many as four times, before they can reproduce. This necessity has resulted in special adaptations of function and structure for attachment.

The adaptation of function is shown in the use made by the ixodid ticks of the front pair of legs. As one approaches the free tick, these legs can be seen waving in the air, while with the others it holds to its support. When a host comes in contact with them, they cling to it most tenaciously with these legs, to determine which fact one has but to pass a finger rapidly over a cluster of the seed ticks. An examination shows the legs to be especially fitted for attachment.

The adaptation of structure for protection is represented in the case of the engorged larvæ of *Argas miniatus*. Up to within a few hours of dropping, these larvæ are globular in shape; but at this time they flatten and assume the typical Argas shape. This flattened form, common to all of the other stages, permits the ticks to crawl rapidly and to secrete themselves in cracks and crevices protected from the wily fowl. In the Ixodinæ we find what may be considered specially adapted mouthparts, which, being unusually long, penetrate deeply and prevent their easy removal.

In the adaptation of habits favorable to attachment and protection we find most striking illustrations of natural selection. Such adaptations are: First, in molting; second, in attachment to any host; third, to habits of host; and, fourth, acquired greater vitality. There is a great disadvantage in dropping to molt, for it necessitates long periods of waiting, and results in a high percentage of mortality from not finding a host. This disadvantage is overcome by some species which have acquired the habit of molting on the host, for example, by Margaropus and by *Dermacentor nitens* and *D. albipictus*.

To this class belong several other species which have partially overcome this disadvantage by passing the first molt upon the host. Two representatives of this class are the South African species *Rhipicephalus bursa* and *R. evertsi*. It has been overcome entirely by *Ornithodoros megnini*, the spinose ear tick, in a somewhat different way—that is, by passing the first molt upon the host, then feeding sufficiently as a nymph so that following the second molt, which takes place off the host, engorgement as an adult is unnecessary for oviposition and probably never occurs.

Even in species most diverse in their tastes there are hosts especially favored. This in some cases may be accounted for by the great numbers of that host available. In the class which has adapted its habits to the habits of the host, the ticks are confined largely to a host or group of hosts with similar habits. The species *Hæmaphysalis leporis-palustris*, commonly known as the rabbit tick, has adapted itself to the habits of the Leporidæ, the hares and rabbits, and only accidentally attaches to other hosts. It is the habit of the hares and rabbits to remain more or less inactive during the day in their "forms," or resting places, protected by a clump of grass or bushes from enemies, such as birds of prey, their activity being largely at night. The writers have found that this tick following engorgement drops largely during the day; in other words, when the hares and rabbits are in their forms or resting places, to which they return to pass the day. Thus, when the ticks have hatched or molted and are ready to attach, they have little trouble in finding the host. This same habit has been acquired by the fowl tick, *Argas miniatus*, which, in the engorged larval stage, the writers find, drops only at night (except accidentally), when its host, the fowl, is upon the roost. Thus when ready to reattach it is near and readily finds the host, whereas had it dropped during the day when the fowl was on the "run" the chances of its finding a host would be greatly lessened. A habit apparently acquired by *Ornithodoros megnini* is that of crawling to a height of several feet from the ground as a nymph before molting and depositing its eggs; thus when the seed ticks appear ready to attach they will be rubbed off by the horses, cows, or other host, and readily find access to the ear. The extreme agility of the unengorged adults of *Dermacentor parumapertus marginatus* and *Rhipicephalus sanguineus* undoubtedly greatly aids these species in finding a host and in finding a place of attachment before being dislodged by the host. These species furnish what evidence we now have of the adaptation of habits to the habits of the host, but it seems probable that similar habits will be discovered in other species when they have been given sufficient study.

Dr. Nuttall has recently (1911a) discussed a structural adaptation which he believes to have resulted from the interrelationship of

the hosts and their parasites. He observes that in certain species of Ixodes which normally infest wandering animals the hypostomes of the males are strongly armed, while others which attack animals with fixed habitats have practically no armature on their hypostomes. He believes that in some cases the males of these species may never attach to the host. With those species which feed upon wandering hosts, it is necessary for the males, as well as the females, to attach.

It seems probable that in the species which drop to pass their molts greater resistance to high and low temperatures and the power to withstand long periods of fasting have been acquired. On the other hand, some of the species which have acquired the habit of molting on the host have lost in this power of resistance.

As related to protection, the adaptation of habits may be considered under accelerated engorgement, attachment to favorable part of the host, nocturnal habits, habits while awaiting hosts, and habits during molting and oviposition.

Of accelerated engorgements we have several instances among the ticks. These are best illustrated by the fowl tick, which engorges within a few hours at the most. Prof. Lounsbury argues that such ticks are descendants from forms which remained for days at a time on the host. This view is given weight by the habit of the larvæ of the fowl tick, of remaining upon the host for several days to engorge. In the cattle tick, *Margaropus annulatus*, after it has become about one-third engorged, which requires a number of days, complete engorgement takes place and the ticks drop within a comparatively few hours. In this way the chances of destruction, due to removal by predaceous enemies, such as birds, by crushing by the host, or by attack by parasites, have been very much reduced.

Again we find species which have adapted their habits for purposes of protection by attaching to favorable parts of the body, as have *Ornithodoros megnini* and *Dermacentor nitens*, which attach to the inside of the ears. The species of Hæmaphysalis found upon quail, field larks, and other ground-feeding birds in Texas, Louisiana, and Florida, appear to attach only to the head, a place from which they are not easily removed by the fowl. Perhaps the most highly developed habit acquired by ticks for protection is the nocturnal habit of species of the genus Argas. Through this habit of resting during the daytime they escape detection by the fowls, which, upon discovering them, devour them with great avidity. At night the fowls go to roost and the ticks have little trouble in finding them and engorging at a time when their hosts are inactive; thus the ticks largely escape detection and destruction.

The habit of the immature stages of the gopher-tortoise tick (*Amblyomma tuberculatum*) of burying themselves in the soil after

becoming engorged appears to be an adaptation for protection and to provide moisture for molting.

The clustering of the larvæ undoubtedly decreases the rapidity of drying out and thus increases the longevity of that stage. The larvæ of *Dermacenter albipictus*, a species which is now being studied, remain in dense clusters for months on the sand in tubes without making any effort to find a host. This seems to be a protective habit developed in order to pass the time between generations.

The engorged females of most of our species have a habit of finding protection as soon after dropping as possible in order that they may deposit their eggs unmolested.

MATING AND FECUNDATION.

Fertilization may take place during attachment or after the females have engorged and left the host. Several instances have been reported in which mating has taken place before attachment to a host, but whether such unions result in fertilization has not been determined. Thus E. G. Wheler (1899, p. 632) collected unengorged specimens of *Ixodes ricinus* on herbage which mated when kept in confinement. He also observed mating of a male and an engorged female taken from a deer.

Mr. J. D. Mitchell, as reported by Hunter and Hooker (1907), observed a pair of *Amblyomma americanum* clinging to herbage with the mouthparts of the male inserted in the genital orifice of the female, and Mr. C. W. Howard (1909) reports a similar observation in the case of *Rhipicephalus ecinctus*.

Dr. H. T. Ricketts (1909, p. 99) states that with *Dermacentor venustus* fertilization will take place even when the ticks are not on an animal host. Just what he intended to convey is not clear, but it would appear that he meant that copulation took place away from the host, probably after removal. The writers have observed this habit in *Ixodes scapularis*, both upon and off the host. An unengorged, unattached female taken in the field from a hunting dog and placed in a pill box with unattached males taken from the same dog was shortly after found in this relation with one of the males. These observations do not prove, however, that fertilization follows such unions, and investigations may show that the engorgement of blood by one or both sexes is necessary.

With the Argasidæ fertilization takes place after the adults have engorged and left the host. Thus the nymphs of *Ornithodoros megnini* leave the host, molt, and without further feeding are fertilized and commence oviposition. Prof. Lounsbury states (1903a, p. 268) that in *Argas miniatus* mating takes place a few days after engorgement. He says that the male inserts the rostrum into

the genital orifice of the female but that he does not know the significance of this action. We have observed copulation in *Argas miniatus* in a number of instances. The act has been witnessed most frequently a few hours after engorgement. The male crawls beneath the female and inserts the hypostome into the female genital orifice. In about five minutes the mouth parts are withdrawn and the male moves slightly forward and deposits a large spermatophore, the end of which is inserted in the female aperture. The contents of the spermatophore appear to be pressed out by the body of the male. The empty spermatophore is usually left attached to the posterior margin of the genital opening of the female. This collapsed sack was found to measure about 0.387 mm. long (parallel with the axis of the tick) by 0.502 mm. broad. Nuttall and Merriman (1911) have made very careful observations on the copulation of *Ornithodoros moubata;* the process is very similar to that which occurs in *Argas miniatus.*

With the Ixodidæ copulation usually takes place on the host, although males of a number of species have been observed with the mouth parts inserted in the genital openings of females while off the host. This habit was first observed by De Geer (1778). Among the ixodid ticks it appears to be the most common in species of the genus Ixodes, having been observed by Wheler (1906, p. 425) in *I. ricinus* and *I. hexagonus* and by the writers in *I. scapularis* and *I. californicus.* Samson (1909), who has made observations on this act in *Ixodes ricinus,* states that no spermatozoa were found in the female genital pore when a male which had its mouthparts inserted was removed. However, males were observed to withdraw the mouthparts and to bring the genital pore into contact with that of the female, then reinsert the beak as though pushing the spermatophore into the female orifice. This habit of the male in introducing the hypostome into the vulva, so commonly observed among species of the genus Ixodes, has been less frequently observed in other ticks. Wheler (1906, p. 425) has also observed the habit in *Ceratixodes putus.* Dönitz (1905, p. 125) reports its occurrence in *Rhipicephalus appendiculatus* and *R. evertsi* as well as in *I. ricinus,* and Lounsbury (1905) has observed it one or more times in *Amblyomma hebræum, R. evertsi, Margaropus decoloratus, Argas persicus,* and *Ornithodoros savignyi cæca,* as well as in *I. pilosus* (1900c).

With the species which molt upon the host, the male usually reattaches very shortly after the nymphal skin is shed and, following a short period of feeding, goes in search of the female. In most of the species which drop to molt it seems to be necessary that the male attach and engorge blood before the sexual instinct becomes manifest. The period required for fecundation appears to vary considerably. Some species, namely, *Margaropus annulatus, Der-*

macentor nitens, Rhipicephalus sanguineus, and others, remain mated for nearly the entire period that the female remains attached. Others, including the species of Amblyomma that we have studied, remain in the position of copulation for comparatively short periods.

Considerable difficulty has been experienced by the writers in getting the sexes of the species of Amblyomma and Dermacentor (except *D. nitens*) to copulate, and there remains much to be learned in relation to this habit.

Prof. Lounsbury has made some interesting observations of the mating of *Amblyomma hebræum,* a species the habits of which are quite remarkable. He has found that the female goes in search of the male, the latter accepting the female only after having attached and fed for several days.

SECRETIONS.

Several investigators have found that ticks secrete substances that prevent the coagulation of blood. Thus Sabbatini (1898) demonstrated that the bodies of *Ixodes ricinus,* both male and female, contain an anticoagulin, and Nuttall and Strickland (1908) demonstrated the presence of anticoagulin in the salivary glands and intestines of *Argas miniatus.* Christophers (1906, pp. 10, 45) reports observations first made by Donovan of a secretion from the coxal glands of *Ornithodoros savignyi* when engorging. This secretion, which was abundant (several large clear drops forming in quick succession), is alkaline to litmus and has a marked effect in preventing the coagulation of blood. A similar secretion has been observed by the writers to be exuded from the coxal glands of *Ornithodoros turicata, O. talaje,* and *O. megnini.* Studies of the glands of ticks have recently been made by Elmassian (1910) and Künssberg (1911).

EXCRETION.

All ticks excrete more or less, particularly while attached to a host and engorging. During incubation and when about one-half of the period has passed, a white spot appears at one side of the egg. This spot, which is apparently an excretion of the embryo, is the first gross sign of the viability of the egg. After hatching this excretion still adheres for some time to the anus of the larva, but is finally removed. When seed ticks are hatched out in tubes the sides often become spotted with the white excretions. In the free stage after each molt small drops of either white or black excrement are voided, but it is during the engorgement of the adults that this is particularly noticeable. The ticks of the genus Dermacentor are the most offensive in this respect and none can compare with *Dermacentor nitens,* which, while engorging, constantly excretes a substance which, when dry, resembles coagulated blood.

CANNIBALISM.

A phenomenon closely related to cannibalism has been observed in a few instances. Hunter and Hooker (1907, p. 35) recorded an observation upon that habit. Among specimens of *Margaropus annulatus* which had been sent to the laboratory in pill boxes was found a male with its hypostome deeply inserted in the side of an engorged female. Another instance has come to our attention in a figure by C. A. Barber (1895) of *Amblyomma variegatum* (*Hyalomma venustum*) showing a male attached to the posterior end of an engorged female.

In two instances in the course of our investigation Mr. Wood has observed adults of *Ornithodoros turicata* to attack and imbibe a large amount of blood from the body of a recently fed adult of the same species. The specimens from which blood was taken did not seem to be injured by the bite of their fellows.

On April 18, 1910, a box was received at the laboratory which contained two females of *Dermacentor venustus* taken on a horse at Lakeside, Wash. When received the smaller female, which was slightly engorged, was attached to the fully engorged individual at a point between the genital opening and the coxa. In the evening of April 18 the small female was found to have detached, leaving the other somewhat distorted in the region of attachment. The injured female began depositing on April 21, but died a few weeks later after laying but 150 eggs, all of which were shriveled and failed to hatch.

MULTIPLICATION.

There is a great variation in the rate of multiplication of ticks, due to the fact that some species pass one or both molts while upon the host, while others drop for both. The ticks which drop for both molts must find a host three separate times before eggs can be deposited. Thus their chances of becoming adult are lessened, as compared with the species which pass both molts upon the host, by the proportion of 3 to 1. Those which drop to molt have overcome this great disadvantage to some extent through a greater resistance to heat, cold, etc., while awaiting the host, and through depositing larger numbers of eggs. It is well known by zoologists that the number of offspring produced by an animal is in inverse proportion to the chances of their reaching maturity. Thus with ixodid ticks many thousands of eggs are produced. As will be seen by the accompanying table the greatest number of eggs recorded by us as deposited by a single individual was 11,265, which were deposited by *Amblyomma maculatum*. Mégnin (1904) has recorded 12,000 eggs as being deposited by *Hyalomma ægyptium*, Barber (1895) 20,000 as deposited by *Amblyomma variegatum*, and Lounsbury (1899) estimates the maxi-

mum number deposited by *Amblyomma hebræum* at 20,000. The comparative reproductive capacity of the ticks which we have studied is shown in Table II.

TABLE II.—*Reproductive capacity of the species of ticks studied.*

Species.	Number of ticks recorded.	Number of eggs deposited.			
		Maximum.	Minimum.	Average.	Maximum number recorded by other observers.
Amblyomma americanum	12	8,330	947	3,054	6,519 (Morgan, 1899).
Amblyomma cajennense	13	4,789	2,384	3,536	7,240 (Williams by Newstead, 1909).
Amblyomma dissimile	2	1,655	1,573	1,614	1,784 (Newstead, 1909).
Amblyomma maculatum	7	11,265	4,560	8,282	
Amblyomma tuberculatum	2	5,481	2,197	3,839	
Argas miniatus	21	874	252	537	
Dermacentor nitens	12	3,392	2,149	2,784	
Dermacentor occidentalis	6	4,555	2,373	3,247	
Dermacentor parumapertus marginatus.	6	4,660	855	2,502	
Dermacentor variabilis	11	6,855	2,808	4,776	7,378 (Morgan, 1899).
Dermacentor venustus	11	7,396	2,496	5,422	4,820 (Cooley, 1909).
Hæmaphysalis leporis-palustris	4	2,240	1,112	1,517	
Ixodes kingi	3	4,706	1,556	3,179	
Ixodes scapularis	[1] 1	3,000	3,000	3,000	
Margaropus annulatus	10	4,547	2,127	3,424	5,105 (Graybill, 1911). 4,500 (Newell and Dougherty, 1906).
Margaropus annulatus australis	5	3,975	2,492	3,072	3,046 (Rohr, 1909).
Ornithodoros megnini	13	1,207	358	760	
Rhipicephalus sanguineus	12	2,616	360	1,602	

[1] Number of eggs estimated.

Figuring, on the basis of four generations in the Gulf States, that half of the resulting adults are females, and that 2,000 eggs are deposited by each female, Mayer (1906) has estimated that two Margaropus eggs carried over the winter and hatched by April 15 would increase to a total of 6,750,000,000 ticks by October 15, if all the females found hosts and developed. It is at once seen that this is a theoretical estimation, as only a small percentage of the ticks ever finds a host.

LOCOMOTION AND DISSEMINATION.

Experiments have been made by different persons to determine the part that locomotion may play in the dissemination of replete females of the cattle tick. Hunter and Hooker (1907) found them to travel 123 inches in the course of 52 minutes, always traveling away from the light. Engorged females of *Dermacentor venustus* have been observed by us to crawl as far as 33 inches in 4 minutes. They seem to crawl in the direction in which they are headed without regard to light. The engorged females of all species usually crawl into the first obscure nook, crack, or crevice that they find, and for this reason usually do not travel far from where they drop. Little has been done to determine the distance

that ticks may go while in search of a host. Although the distance traveled by seed ticks, as the writers have observed them on grass in cages, is comparatively slight, the adults may be found to crawl considerable distances. This appears to be the case with the brown dog tick (*Rhipicephalus sanguineus*), which is very agile and constantly moving about when not attached. We have found the males of this species to travel from one dog to another when the hosts were lying asleep in the laboratory. The adults of *Dermacentor parumapertus marginatus* can crawl considerable distances in a comparatively short time, their movements being very rapid.

The usual method by which ticks are disseminated is by the natural movement of the hosts or by the shipment or driving of the host from one locality to another. The following are good illustrations of how far ticks may be carried upon their usual hosts: The cattle tick has been found on ponies in Michigan, as well as upon cattle at various times in the extreme northern parts of the United States prior to the establishment of a quarantine against this tick. *Amblyomma dissimile* has been brought into Texas on iguanas from the Isthmus of Tehuantepec, and according to Barber (1894, 1895) *Amblyomma variegatum* (*Hyalomma venustum*) has been introduced into the Leeward Islands on cattle shipped from Senegal, in Africa. That there is abundant opportunity for ticks to be carried long distances in this way may be seen from the fact that *Ornithodoros megnini* has been found to remain upon a host as long as 209 days before dropping. Birds, especially migratory species, may carry ticks long distances. In one instance Mr. W. V. King, of the Bureau of Entomology, found a number of engorged larvæ of a species of Ornithodoros, which appears to be confined normally to the Southern States, on the head of a bird in northern Wyoming. Among other means of natural dissemination which may be of importance are streams and floods (as mentioned by Hunter and Hooker, 1907, p. 24), high winds, and the movement of animals which are not hosts but to any of which ticks may cling for a greater or less time. Ticks may be artificially disseminated by means of the movement of various farm commodities, especially hay; by crates in which poultry or animals have been confined; by the shipment of hides of animals, and in the clothing of man.

SEASONAL HISTORY.

The seasonal prevalence of ticks varies considerably from year to year with the temperature conditions. In some species the winter is passed in the egg, unengorged larval, nymphal, or adult stages. Females which drop engorged after the approach of cold weather stand a very poor chance of surviving. Ricketts (1909a, p. 102) reports having obtained ticks, largely engorged nymphs, at Hamil-

ton, Mont., late in December and in the first part of January from horses which had been in the hills during the winter. This species is undoubtedly *Dermacentor albipictus*, which has been found during our investigation to be present on horses and cattle in large numbers in both the nymphal and adult stages throughout the winter months. Thus it appears that even in the Boreal Zone some species are active during the winter months. When the season is not too hot and dry the ticks are most numerous during late summer and early fall. In the case of most of our species, we have found that all stages may occur on hosts at the same time of the year, there being no well-defined restriction of certain stages to any one season.

In our work with *Dermacentor venustus* we found it almost impossible to get adults to attach to hosts during the summer months. They remain quiet for long periods with their legs curled up close to the body. This, together with the fact that very few adults are seen on hosts in nature after the middle of June, seems to indicate that there is a period of æstivation during the latter part of the summer.

Mayer has considered it possible that the cattle tick, which must find but one host in order to complete its cycle of development, may, where hosts are plentiful, pass as many as four generations in a single year. As the number of generations depends entirely upon the finding of hosts, it is impossible to say what the average annual number of generations would be. With the 3-host species, on the average probably not more than one generation is passed in a year, and in many cases a period of two years or even longer may be required for a single generation.

METHODS EMPLOYED IN STUDIES OF TICKS.

RECKONING TEMPERATURE.

Although it is now generally understood that the temperature above which active metabolism takes place in insects, ticks, and other cold-blooded animals may vary with each species or even with each stage in the development of a single species, we have not attempted, in preparing this bulletin, to determine such temperatures, but have thought it best to use 43° F. as the zero of effective temperature in all our computations. However, from the data furnished with each table one can work out the approximate effective temperature for a given stage. In figuring the total effective temperature required for the incubation of eggs we have commenced with the calendar day on which the eggs were deposited and included the day on which hatching occurred. In computing the total effective temperature required for molting we have commenced with the day following dropping and included the day upon which molting took place. The above periods have been used in determining the mean tempera-

tures. In reckoning the effective temperature where the daily mean does not fall below 43° F. the average daily mean for the period covered may first be obtained; then, by subtracting 43° F. (the "zero" of effective temperature) from this mean and multiplying the product by the number of days covered, the total effective temperature can be readily calculated. Since the monthly mean temperature must first be obtained, by following this method much time may be saved in calculating the total effective temperature. Where the mean temperature for one or more days during a given period falls below the "zero" of effective temperature (43° F.), the effective temperature for each day should be obtained and added in computing the total effective temperature. Our records on the incubation of eggs are based largely upon lots kept in glass tubes on sand.

RECKONING PERIODS.

In determining periods it has been the practice to commence with the day following dropping or hatching of the tick and to include the day oviposition commenced, molting occurred, or death took place, as the case might be. In calculating the period of incubation the day of oviposition as well as the day of hatching has been included, as in the case of the determination of effective temperatures.

In the life-history work in the laboratory it was the daily practice between the hours of 3 and 5 p. m. to separate the eggs from the females,[1] the molted ticks from those not molted, and to note the hatching of eggs. In case more eggs had been deposited than could be counted within this period, they were isolated in pill boxes and counted the following day. After the eggs were counted they were placed on sand in tubes. Thus the records of egg counts, moltings, and other life changes, as recorded in the tables here given, are for periods of about 24 hours.

In determining the periods of attachment, when these records have been made by the utilization of the bovine scrotum, it has been the practice to place the larvæ, nymphs, or adults in a cotton bag secured to the host. The bag was examined at periods of 10 to 12 hours and attachment noted. Ticks still in the bag at the end of 24 hours were usually removed. In some cases, however, ticks have been kept in the bag for longer periods, but attention is called to these cases where they occur. Some ticks have been found to remain upon the host for several days unattached or without attaching securely. This might or might not occur naturally, but must be taken into consideration. Where small mammals were employed for the engorgement of ticks, in most cases the individuals were examined at frequent intervals, so that the time of attachment was noted rather accurately.

[1] In determining the number of eggs deposited by a species only females that have been permitted to drop should be used.

This class of animals was usually allowed to remain in the attachment cages for 5 or 6 hours, specimens not attached at the end of that time being returned to rearing tubes.

REARING TICKS.

In rearing ticks one of the first considerations is to eliminate, so far as possible, the danger to the experimenter of infection by disease-bearing species. This requires great care in manipulation, and complete isolation, by water and grease or some other substance, of all specimens likely to be infected.

Although it is desirable that the usual host be used in determining the parasitic periods, so that variations from the normal condition may be eliminated, this was not always possible. In a few instances small wild mammals which were captured in nature have been utilized for the rearing of ticks and the study of their habits. Animals which have become infested in nature may often be successfully employed in the study of the habits of the ticks with which they are infested. Most of the species which we have studied attach to domestic animals, and as nearly all of these attach to a bovine, we have largely made use of this host in determining the parasitic periods and habits of the species. The method found most satisfactory is that suggested by Prof. C. P. Lounsbury, of attaching a bag over the scrotum of a bovine. In this way the various stages of ticks were applied, examinations made, and the ticks removed as they dropped, and comparatively few were lost. All of the ixodids, except certain species of Ixodes, thus applied by the writers, have attached in one or more stages. Some species, *Dermacentor variabilis* in particular, attach with considerable reluctance. By removing the bag and with it the unattached ticks at the end of a given period and then replacing the bag and making examinations twice daily and removing the engorged ticks from it, the exact periods of engorgement were determined. In order to prevent the removal of the bag from the scrotum by the host a harness has been employed in some instances and in others leather or wire muzzles have been found satisfactory (Plate I). With the ticks which pass both molts upon the host, as do *Margaropus annulatus*, *Dermacentor nitens*, *D. albipictus*, and *O. megnini*, it is a comparatively easy matter to follow the life cycles, but with those which drop from the host to molt, as is the case with most of our North American species, it is much more of a task. With those species which drop for each molt one must succeed in getting the same individuals to attach to the host and catch them as they drop three or more different times. After dropping each time they must be isolated under favorable conditions and frequent examinations made to determine the periods of molting and ovipositing. In order to present satisfactory information upon these periods the periods

must be recorded in connection with the thermometric readings, as all life processes when the ticks are off the host appear to be affected by variations in temperature. Our out-of-doors records are based upon temperatures registered by the thermograph shown in Plate II, figure 1. Those indoors were based on a similar thermograph kept in the room with the ticks and regulated by standard thermometers.

In determining the life cycle of ticks that attach to small animals, such as dogs, rabbits, squirrels, fowls, and others, a satisfactory arrangement found has been the use of a cage made of wire of about $\frac{1}{4}$-inch mesh, permitting the ticks to drop through into a pan beneath. (See Pl. I, fig. 4.) This cage, made with a wooden frame, should have the joints set in white lead or putty in order to eliminate all possible hiding places into which the ticks might crawl for protection. Nails inserted in the frame serve as posts, preventing the ticks from crawling back to the cage. In the pan or tray under the cage may be placed strips of paper, beneath which the ticks will crawl. Some thick and absorbent paper, such as blotting paper or pressing paper, should be placed in the bottom of the tray or pan to absorb the urine. When this is used it is not necessary to eliminate succulent food from the diet of the host animal. It has been the practice to place a ring of white axle grease about the rim of the pan or tray to prevent the escape of any of the ticks which have dropped. Another and more satisfactory way of preventing their escape is by setting this pan or tray in a larger one filled with water. When the examinations are made the tray can be removed, the ticks collected, and the cage cleaned with little difficulty. The plan of this tray was first suggested to the writers by Prof. Lounsbury and is similar to that which he has used. A more satisfactory cage than the one just described for use with small hosts, such as guinea pigs and rabbits, has been made by taking two wire desk trays or baskets and fastening them with rubber bands, one bottom side up over the other, as shown in Plate I, figure 1. The principal advantage of this kind of cage over the other is that places for hiding are practically eliminated, thereby allowing quicker examinations. Though the cages may be made of other coarse-mesh wire screen, the desk trays are to be preferred. To prevent the animals from shaking the ticks across the moat an 18-mesh wire-screen band is placed around the cage, with its base set in the tray and the top extending a few inches higher than the cage.

In order to keep the ticks upon or near the host while attaching and to prevent their escape, a canvas cage was used. A square wooden frame was first made, to which the canvas was fitted just tight enough to permit of the removal of the frame so that the canvas bag could be inverted and readily cleaned.

It has been found that certain small animals used as hosts for breeding ticks learn after a few infestations to keep up a constant fight against ticks. This habit necessitates special attachment cages and also great care to prevent the ticks from being scratched off after they are once attached. A number of different forms of attachment cages have been devised. The utility of these varies with the individual animal used as a host as well as the species of host and species and stage of ticks applied. In some instances it has been found that successful attachments may be secured by placing the host and ticks in a close-fitting, loose-woven cotton bag with the end tied up. Another method of keeping the host quiet while the parasite is allowed to attach is to put the animal in a cylinder of 4-mesh wire. The cylinder should be large enough to be comfortable, but not large enough to allow the animal to turn around. In some cases a rectangular piece of 4-mesh wire is bent into the shape of a V-formed trough about 2½ inches on each side and 5 or 6 inches long. This trough-shaped piece is inverted and placed over the back of the animal within the cylinder, the front end being drawn down tightly over the head to prevent shaking. The cylinder containing the animal is then placed in an inverted bell jar in a pan surrounded by a moat. (See Pl. I, fig. 2.) The animal is kept in this cage only for a sufficient time to allow the ticks to attach. Small animals which do not fight the ticks may be placed in an inverted bell jar over a moat without using the cylinder. The bell jar should be covered with coarse-mesh screen held down by rubber bands stretched down on different sides to the handle of the jar.

In order to determine the parasitic period of *Ornithodoros megnini*, cotton bags were fastened about the ears of the host animal and held in place by tying the puckering strings to rings in a cord fastened about the horns, as shown in Plate I, figure 5.

In engorging nymphs and adults of *Argas miniatus*, it has been found necessary to place a hood about the fowl's head in order to prevent it from devouring the ticks. Our experience has shown it to be necessary to bind the legs of the fowl sufficiently close together, with a strip of cotton cloth, to prevent an attempt at removing the hood and possible strangulation. Neither the hood of cheesecloth nor the cord, if properly applied, will occasion undue restlessness if the fowl is accustomed to handling.

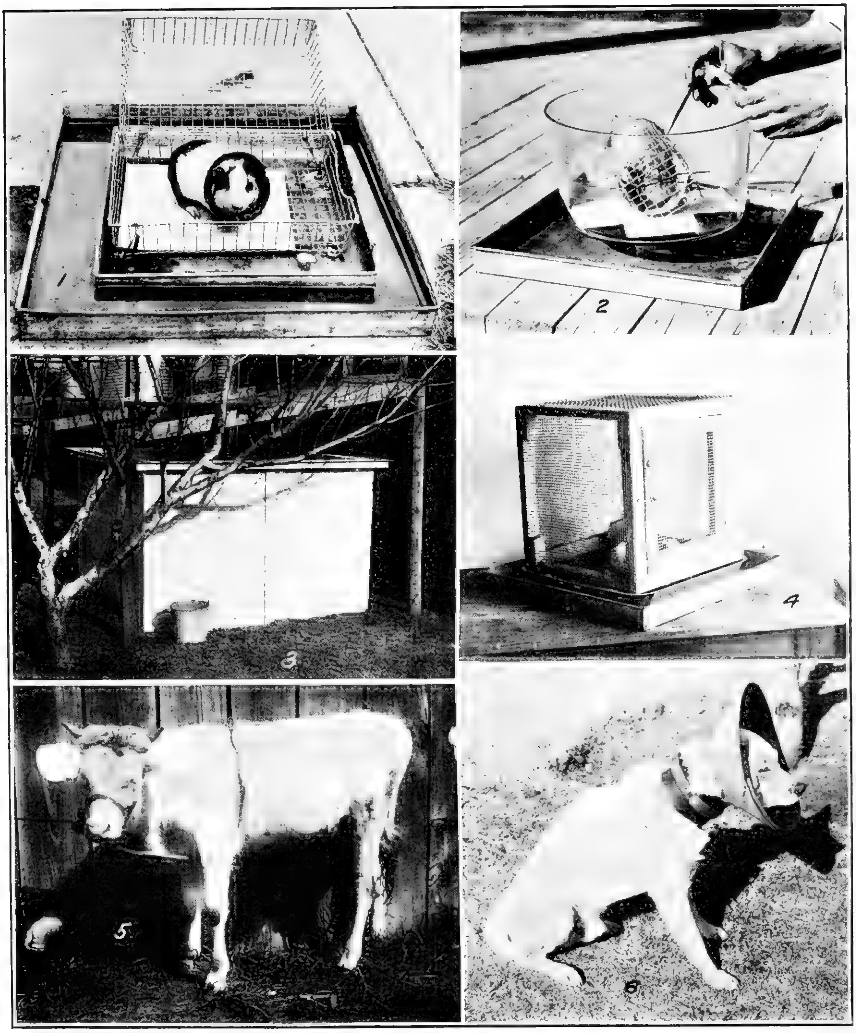
In applying ticks to tortoises it is necessary to tie a bag about the shell behind the front legs, as otherwise the ticks are likely to be devoured.

While some ticks attach immediately after being placed upon a host, others wander about for some time before attaching, and with some species only part will attach, even though kept for several

days in the bag attached to the host. In the observations here recorded those that had not attached at the end of 24 hours were removed from the bag. Others that might not have attached but that were upon the host were permitted to remain. Thus the observations reported actually indicate what takes place in nature.

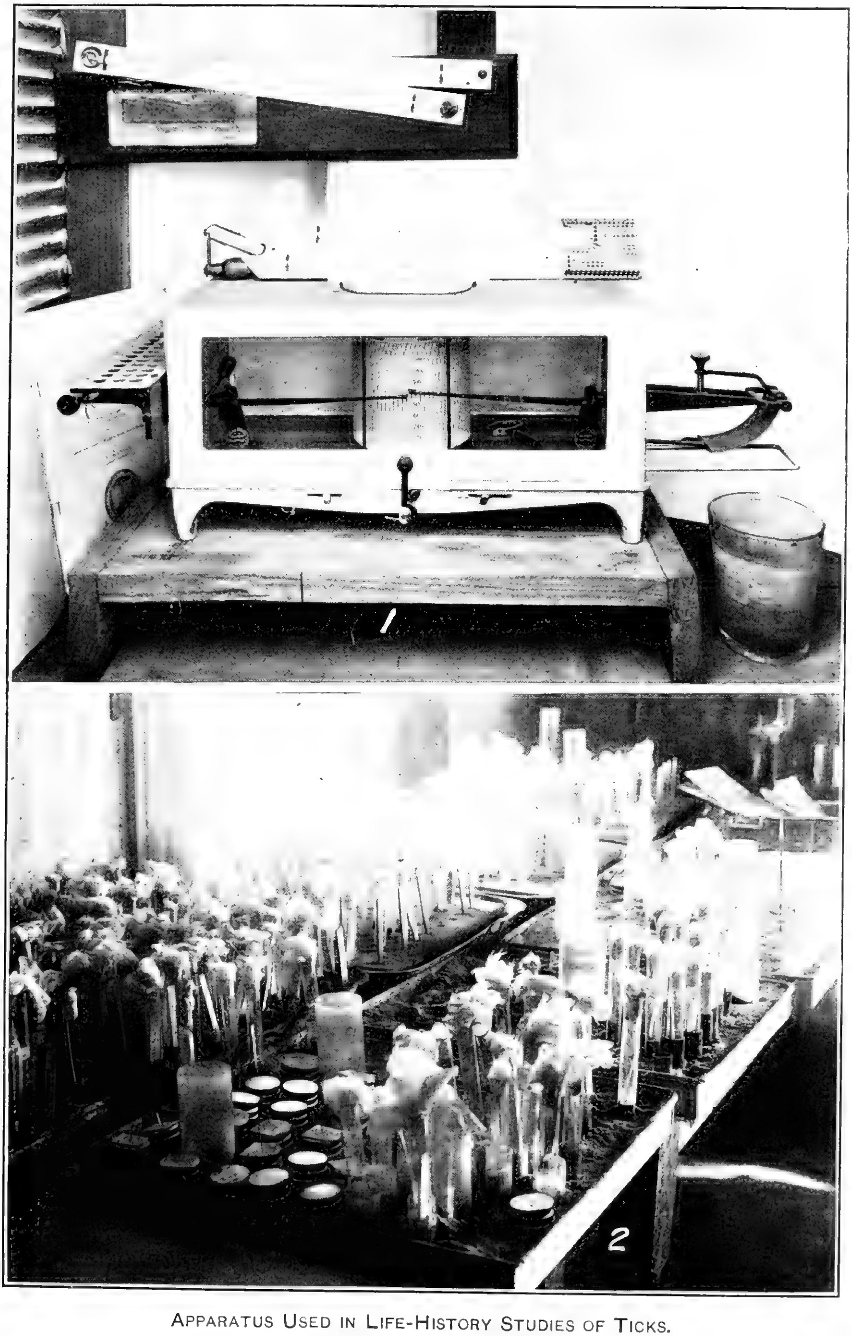
In a few instances rabbits, guinea pigs, and fox squirrels have allowed ticks to become engorged when no provision was made to prevent the host from scratching. Usually, however, special precautions must be taken to prevent the host from displacing the parasites. With most of the small animals, a leather collar has been successfully utilized. These collars are made by cutting out a disk-shaped piece of leather with a hole in the center slightly larger than the neck of the animal. The width of the collar should be at least equal to the distance from the neck to the chin. In applying the collar the ends are lapped and fastened with brass rivets. By keeping the outer edge of the collar circular, the disk takes the form of a truncated cone with base extending forward around the head. (See Pl. I, fig. 6.) When dogs are used, a leather band 4 or 5 inches wide should be placed around the neck behind the other collar so as to keep it forward. In order to protect ticks attached on the ears of rabbits, a disk-shaped collar made of light boards is employed. This collar should be made in two parts, the halves being fastened together with rubber bands so as to permit of removing the collar easily and to make it flexible.

As the engorged ticks are removed from the bag or tray, it has been found that favorable conditions for further development are furnished by placing them in pill boxes upon moist sand. These pill boxes are prepared by puncturing the tops and bottoms, or still better, they are furnished with gauze tops, to permit of free circulation. Still more favorable conditions are furnished by inserting sand in test tubes from which the bottoms have been removed. The bottoms of tubes may be removed in a satisfactory manner by plunging the tubes into cold water after they have been heated by friction produced by rubbing with a string wrapped around the tube at the point where the cut is desired. These tubes should always be used with those species which, in the immature stages, have a habit of burrowing into the sand before becoming quiescent. As stoppers for the tubes, absorbent cotton will largely prevent too humid an atmosphere, if protected from rains. A large tray, as shown in Plate II, figure 2, has been used filled with sand into which the tubes have been inserted and on which the pill boxes have been kept. By subirrigation the amount of moisture furnished can be kept nearly constant without interfering with the pill boxes. This subirrigation is best furnished by use of a large glass tube extending to the bottom of the sand; water poured into this will gradually percolate through and moisten the entire surface. In most of our



APPARATUS AND CONTRIVANCES USED IN LIFE-HISTORY STUDIES OF TICKS.

Fig. 1.—Rearing cage. Fig. 2.—Bell jar containing attachment cylinder and animal. Fig. 3.—Outdoor attachment and engorgement box. Fig. 4.—Dropping cage. Fig. 5.—Bull with harness. Fig. 6.—Dog with collar. (Original.)



APPARATUS USED IN LIFE-HISTORY STUDIES OF TICKS.

Fig. 1.—Thermograph and apparatus for weather records. Fig. 2.—Pans with glass tubes and pill boxes, in and on moist sand. (Original.)

longevity experiments in the laboratory we have used test tubes with the bottoms removed and placed in trays with moistened sand. The mouths of the tubes are closed with absorbent cotton. Observations can readily be made through the glass without disturbing the ticks and the air in the tube is kept moderately humid. For longevity experiments out of doors, we have made use of $1\frac{1}{2}$-inch glass tubing cut in lengths of about 10 inches. In one end of these tubes about 2 inches of moist sand and clay is firmly packed to prevent the escape of the ticks through the bottom. These tubes are then set in galvanized-iron cylinders which are sunk into the soil. The soil from the inside of the cylinder is removed to a sufficient depth to allow the surface of the dirt in the tube to be on a level with the surrounding earth. In place of an absorbent cotton stopper a piece of bleached cotton was firmly tied over the top with rough cord, which would stand prolonged exposure without breaking. If exposed to rains but largely protected from the sun during the warmer months the longevity can be determined under normal but favorable conditions. The above methods have also been employed in obtaining preoviposition and oviposition records. Most of the longevity records here reported are based on tube experiments, but in work with *Margaropus annulatus* we have also placed engorged females collected within 24-hour periods in clumps of grass, about which screen cages were set to prevent intrusion, and determined the longevity by recording the dates seed ticks first appeared upon the grass and the dates the last could be found.[1]

NATURAL CONTROL.

CLIMATIC CONDITIONS.[2]

Cold appears to be the most effective check upon the spread of some species, while heat and a small or an excessive rainfall are equally effective with others. The effect of atmospheric humidity is undoubtedly an important factor also. Dr. Arnold Theiler (1908) has found the larvæ of *Margaropus annulatus decoloratus* to die within 30 minutes when exposed to a temperature of $-5°$ C. (23° F.) for 48 hours, although they are not affected by an exposure to that temperature for 24 hours. We have found that with the cattle tick, engorged females kept in tubes without stoppers were killed at Dallas in October when the temperature fell to 13° F. for a few hours. Eggs of several species of ixodids have been found to be rendered nonviable by exposure to sun on bare ground for a few hours when the atmospheric temperature was about 101° F. The eggs of

[1] This can readily be done by running the bared hand and arm over the grass.

[2] The admirable studies of the cattle tick by Cotton and Voorhees (1911) have come to hand too late to note in this bulletin. Cotton reports that all adults of *M. annulatus* exposed at 14° F. were killed; that when unprotected all the larvæ are killed at 4° F. and all the eggs at 2°. It was found that when more than 25 per cent of the original weight of the eggs of this tick is lost they will not hatch.

the ixodid ticks often fail to hatch when not supplied with moisture during periods of excessive heat in summer or during dry winters when the incubation period is very long. Flooding apparently has little influence in controlling ixodid ticks, as the larvæ of *M. annulatus* have been found by Hunter and Hooker (1907) to survive a submergence of from 10 to 157 days. Vorontzov (1907) states that the eggs of *Ixodes ricinus* may retain their vitality under water from fall to spring, and Hunter and Hooker have found the eggs of *M. annulatus*, when submerged, to hatch in about the normal period.

PREDACEOUS ENEMIES.

Sowbugs, which have been supposed to destroy eggs of ticks, have been shown by Pierce (1907, pp. 17 and 22) to consume comparatively small numbers even when confined with no other source of food supply. *Solenopsis geminata*, an ant widely disseminated in this country, is thought to be an important enemy of ticks. Rats and mice feed upon ticks and field mice undoubtedly assist in a limited way in destroying the engorged females. Wellman (1906b) has observed a reduviid bug (*Reduvius* [*Opsicætus*] *personatus*) feeding on engorged ticks in Africa.

Domestic fowls have been found to destroy cattle ticks that drop about farm buildings and even to jump up and pick them off dairy cows. A hen has been observed by the writers to devour with avidity as many as 150 engorged females of *Margaropus annulatus* in a half day. Quite a number of species of birds have been observed to light on cattle and feed on the engorged ticks. Several species of blackbird, including the great-tailed grackle or "jackdaw" (*Megaquiscalus major macrourus*), bronzed grackle (*Quiscalus quiscula æneus*), and Brewer's blackbird (*Euphagus cyanocephalus*) are known to do so in Texas. Kingbirds (*Tyrannus tyrannus*) have been observed to do this in Louisiana, and Newstead (1909) reports that in Jamaica the savannah blackbird or tinkling grackle (*Quiscalus crassirostris*) and the ani or "parrot-billed blackbird" (*Crotophaga ani*) have the same habit. McAtee (1911a) states that Mr. H. S. Barber has observed red-eyed cowbirds (*Tangavius æneus involucratus*), boat-tailed grackles (*Megaquiscalus major*), and another species of blackbird picking ticks from cattle at Brownsville, Tex. At Tampico, Mexico, Bishopp observed the groove-billed ani (*Crotophaga sulcirostris*) to feed upon *Margaropus annulatus australis*, attached to cattle. This species and the red-winged blackbird (*Agelaius phœniceus*) are said by Moreau (1907, figs. 8–9) to prey upon cattle ticks in Mexico. Cherry (1892, p. 325) states that the groove-billed ani habitually feeds upon cattle ticks in Costa Rica. Bendire (1895, p. 435) states that eastern cowbirds (*Molothrus ater*) and McAtee (1911b, p. 401) says that the fish crow (*Corvus ossifragus*) eat ticks. Other birds in the

stomachs of which the Biological Survey of this department has found ticks (McAtee, 1911a) are the killdeer (*Oxyechus vociferus*), upland plover (*Bartramia longicauda*), meadowlark (*Sturnella magna*), dwarf hermit thrush (*Hylocichla guttata nana*), and house wren (*Troglodytes ædon*). Mr. J. D. Mitchell states that it is the habit of jackdaws to search for and destroy many cattle ticks on the range by inverting the dried dung, which furnishes a favorable protective covering for this tick. Pycraft has called attention (1910, p. 124) to a depraved habit that such birds may develop, citing the tick bird which occurs in Africa as an example:

> Take, for example, the case of the oxpecker or rhinoceros bird (*Buphaga africanus*), a native of South Africa and generally regarded as a species of starling. This bird is commonly found in intimate association with basking herds of cattle and big game, running about all over the bodies of these creatures in its search for the ticks and other parasites which harbor there. Lately, however, this bird has fallen into disgrace, since it has extended its attentions to the horses and cattle of the colonists with anything but happy results. It would seem that in removing ticks from the more tender hides of these animals the birds caused wounds, and at the same time gained a taste for blood, with the result that, where horses and cattle are at all numerous, they become severely persecuted by these birds, who now seek not so much to prey upon the ticks as the hosts thereof, which suffer considerably in consequence. Thus we see how easily long-rooted habits may become changed, and how an originally useful instinct may become depraved. The tough hide of the rhinoceros was proof against the beaks of these birds, and consequently nothing but good resulted from their presence, but, as we have shown, a very different state of things began when the hides of the imported domesticated animals became subjected to a similar inspection. On account of the damage they do the restrictions imposed by Government for their protection have now been removed, but the oxpecker will doubtless long contrive to hold his own in this vast country. The work of the rhinoceros bird in England is performed by the common starling and so far no harm to cattle has been done by reason of injuries inflicted on the hides. Similarly, in East Africa, egrets swarm over the bodies of elephants when they approach the neighborhood of water, apparently, as it has been suggested, for the sake of capturing the various kinds of insects put up by the elephants as they move about.

PARASITES.

Two chalcidoid parasites have been found to attack engorged nymphs. The first of the two, described by Dr. L. O. Howard in 1907 as *Ixodiphagus texanus*, was reared by Hooker from specimens of engorged nymphs of *Hæmaphysalis leporis-palustris* collected by Mr. J. D. Mitchell from rabbits in Jackson County, Tex. The extent of the parasitism and importance have not been determined. Nymphs subsequently collected in that locality were not parasitized.

The second parasite (*Hunterellus hookeri*) was described by Dr. Howard in 1908 from specimens reared by Hooker from engorged nymphs of *Rhipicephalus sanguineus*, collected by Wood from dogs at Corpus Christi, Tex. This species has been found to play an important part in destroying the brown dog tick in southern Texas. As specimens of this latter species have since been reared by Mr. C. W.

Howard in Mozambique, it will probably be found to be a widespread insect.

In addition to serving as intermediate hosts for various species of protozoa of the genera Piroplasma, Anaplasma, and Spirochæta, they apparently play the same rôle for filariæ, as has been reported by Grassi and Calandruccio (1890), Noe (1908), Baldasseroni (1909), Darling (1910), and Smith (1910).

IMMUNE RACE OF CATTLE.

Cattle with Brahman blood appear to be largely resistant to the attack of ticks. According to Borden (1910) this quality persists in animals with one sixty-fourth of Brahman blood. For this reason and the fact that they do not contract splenetic fever a large number have been imported into this country for breeding purposes in the South.

In regard to these cattle, Mohler and Thompson (1911) state that—

> The sebum secreted by the sebaceous glands of the skin has a peculiar odor which seems to be repugnant to insect life. The hide, while it may be as thin as in our domestic animals, still appears to be much tougher and is more difficult to penetrate with a hypodermic needle. The hair is quite short and does not provide favorable shelter for the development of ticks. These three factors are probably responsible for the slight amount of tick molestation which these animals experience.

In our native cattle a considerable individual variation in the susceptibility to tick attack is seen in the same breed of animals. The length of the hair and condition of the skin of the host seem to be the principal factors influencing tick attack.

ARTIFICIAL CONTROL.

Ticks may be controlled by picking or brushing them from the host and destroying them, by smearing or spraying the host with a disinfectant solution, or by dipping the host in a vat which contains a solution sufficiently strong to kill the ticks and not injure the host. For the details relating to these methods reference should be made to bulletins by Mohler (1905, 1906), Graybill (1909), and Hunter and Bishopp (1911b).

The method by which the cattle tick may be eradicated through a rotation (starvation) system suited to the farm or by a combination of rotation and dipping is also described in the bulletins of Mohler and Graybill above mentioned. Additional information will be found in bulletins by Newell and Dougherty (1906), Hunter and Hooker (1907), Cotton (1908), Hunter and Mitchell (1909), and others. Control methods are briefly considered under the several species.

Restriction of the dissemination of some species may be brought about through quarantining the hosts, as has been done with the cattle tick in this country.

DEVELOPMENT OF THE ARGASIDÆ.

The first of the two families of ticks, the Argasidæ, is represented in the United States by 2 genera and 6 described species. We have studied a representative of each of the genera.[1]

All of the argasids so far as known, with one exception, pass their molts off the host. The larvæ of species belonging to the genus Argas that have been studied remain attached to the host for several days while engorging, but the nymphs and adults require only a few hours at most to engorge. The nymphs molt two or three times, following as many engorgements. The adults engorge repeatedly, each engorgement being followed by oviposition. Unlike other species of the genus thus far studied, *Ornithodoros megnini* engorges and passes the first molt upon the host; as a nymph it remains attached to the host for a long period, then drops, molts, is fertilized, and oviposits without engorging as an adult, shortly after the completion of which it dies. So far as known it is the only species of tick that does not engorge in the adult stage. Two species of Ornithodoros (*savignyi* and *moubata*) are known to pass the larval molt before feeding, the latter molting the larval skin while still in the egg.

The periods of oviposition, incubation, and molting vary with the temperature; for this reason temperature records have been included in the tables. With the exception of *Ornithodoros megnini*, the females of the species known engorge and oviposit repeatedly. The longevity of some of the species, particularly those of the genus Argas, is quite remarkable, as is shown in the following table:

TABLE III.—*Maximum longevity recorded for ticks of the family Argasidæ.*

Species.	Maximum longevity of stages.[2]			
	Larva	Nymph, first stage	Nymph, second stage.	Adult.
	Days.	*Days.*	*Days.*	*Days.*
Argas miniatus	164	269	445	880
Ornithodoros megnini	80			638+

Genus ARGAS Latreille.

Six well-established and 4 doubtful species are included in the genus Argas by Nuttall and Warburton in their monograph of the Argasidæ, *miniatus* being placed as a synonym of *persicus*. In addition to *miniatus*, which we have studied, only one other species, *brevipes*, is known to occur in the United States, although *Argas reflexus* has been erroneously reported as occurring here. Several of the species, particularly *miniatus* and *reflexus*, are the source of

[1] Two other species of Ornithodoros (*O. talaje* and *O. turicata*) are being studied.

[2] Longevity of third nymphal stage of *A. miniatus* not determined.

great loss to poultry keepers, due to the removal by them of blood from the fowls, and more particularly because of the transmission by them of spirochetosis.

The species are nocturnal parasites of chickens, geese, pigeons, and other birds and occasionally attack mammals. They remain hidden away by day in cracks and crevices, coming out at night from their hiding places to find the fowl host and engorge with blood.

The life history and habits of *Argas miniatus*[1] as worked out by Lounsbury in South Africa are practically identical with those of *miniatus* as determined by the writers. This tick has been shown to be the active agent in the transmission of the causative organisms of spirochetoses (*Spirochæta gallinarum* and *S. anserinum*) of chickens, geese, and other fowls.

In the larval stage *Argas miniatus* remains upon the host for several days to engorge, but in the nymphal and adult stages only a few hours at most are required. In *miniatus*, the only species of Argas whose life history has been followed, there is a second, and in about one-seventh of the individuals a third nymphal molt, as has been shown by Hooker (1909*c*). As adults, repeated engorgement takes place, each nearly always followed by the deposition of eggs.

THE FOWL TICK.

Argas miniatus Koch.

The common name, fowl tick, is derived from the fact that this species feeds almost exclusively on domestic fowls and is an important enemy of them.

DESCRIPTIVE.

Adult (Pl. III, figs. 5–8).—Males, unengorged, 4.5 by 3.5 mm. to 6 by 4.5 mm.; engorged, 5.5 by 3.5 by 2 mm. to 7 by 4 by 2.25 mm. Females, unengorged, 5 by 3 mm. to 8.5 by 5.33 mm.; engorged, 6 by 4 by 2 mm. to 12 by 7 by 3 mm.

Nymph (Pl. III, figs. 2–4).—Last stages (2d and 3d nymphal): Unengorged, 3 by 2 mm. to 4 by 2.75 mm.; engorged, (premales) 5 by 3.5 by 2 mm. to 7 by 4 by 2 mm., (prefemales) 6 by 4 by 2 mm. to 8.5 by 5 by 2.5 mm. The normal brown color becomes purplish when blood is engorged. First stage: Unengorged, 2 by 1.25 mm. to 2.5 by 1.5 mm.; engorged, 3 by 2 by 1 mm. to 4 by 3 by 1 mm. Brown, the margins of the body and legs colorless.

Larva (Pl. III, fig. 1).—Unengorged, about 0.8 by 0.6 mm., pale yellow to colorless; engorged, 2.2 by 1.5 mm. to 2.5 by 2 mm., dark blue. In one instance a larva dropped on the fourth night following attachment, and before assuming the flattened Argas shape.

[1] We have thought best to refer to the American fowl tick as *A. miniatus;* recent investigations, however, indicate that it is synonymous with *A. persicus*, the name of the Old World fowl tick.

This individual, after assuming the flattened shape, measured only 1.5 by 1 mm.

Egg.—The average size of 10 eggs measured was 0.72 by 0.65 mm. Spherical, dark brown, shining, smooth.

HOST RELATIONSHIP.

This tick is principally a parasite of poultry. A single larva was collected by Mr. J. D. Mitchell on a meadowlark in southern Texas, and Mr. F. C. Pratt found a few larvæ on a wild turkey at Sabinal, Tex. That it may occasionally be found upon mammals and possibly engorge upon and be disseminated by them is shown by the fact that three adults were removed by Mr. J. D. Mitchell from a jack rabbit shot in Maverick County, Tex., in May, 1906.

Lounsbury has found *Argas miniatus* in South Africa commonly to attack geese, ducks, and turkeys, and he states that it has been reported to attack canaries and ostriches. It is well known in Persia as the Miana bug. Nuttall and Warburton found this tick to engorge on rats and mice, but with difficulty.

In the larval stage these ticks remain attached to the host for several days before dropping fully engorged, but in the nymphal stages and as adults they engorge in a comparatively short time, a few hours at the most, and nearly always at night. The larvæ appear to prefer the portions of the body where the feathers are sparse, particularly beneath and on the underside of the wings.

Larvæ placed in a bag on the scrotum of a bovine and left for 24 hours failed to attach. An attempt to engorge larvæ on pigeons was also unsuccessful. On one occasion a single individual of a number of adults applied to a guinea pig attached and became partially engorged.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 1.)

This tick was originally described by Koch from Demarara. In this country (see fig. 1) it has been found to be a very common species in certain sections of southern Texas, and appears to be so at certain points in Florida, New Mexico, Arizona, and California. The Marx collection contains specimens from Iowa. It is very probable that this and other records of the occurrence of this tick in the Central States are based upon specimens introduced into that region, the infestation being only temporary. A careful study of the normal distribution of the species in Texas shows that the limit of its eastern range practically coincides with the division between the Lower Sonoran and Austroriparian faunas. It is widely disseminated in the tropical regions of the New World, having been reported from Mexico, Panama, Jamaica, Cuba, Barbados, Antigua, Martinique, Trinidad, Colombia, British Guiana, and Brazil. It is also found in many parts of Africa, Asia, Europe, and Australia.

LIFE HISTORY.

Observations on the life history and habits of *Argas miniatus* have been reported by Fuller (1896), Brown (1902), Lounsbury (1903a), Hunter and Hooker (1907), Nuttall and Warburton (1908), Hooker (1908, 1909), Galli Valerio (1909), Rohr (1909), and others.

FIG. 1.—The fowl tick, *Argas miniatus:* Distribution in the United States and in part of the West Indies. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the tick. (Original.)

The egg (Tables IV and V).—At summer temperatures at Dallas, Tex., following the first and third engorgements as adults, eggs were deposited as soon as the third day, while after the second engorge-

THE FOWL TICK, ARGAS MINIATUS.

Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph after first molt. Fig. 3.—Unengorged nymph after second molt. Fig. 4.—Engorged nymph after second molt. Fig. 5.—Engorged female, dorsal view. Fig. 6.—Unengorged male, dorsal view. Fig. 7.—Unengorged male, ventral view. Fig. 8.—Engorged female, ventral view. (Original.)

ment eggs were deposited as soon as the second day. In several instances ticks did not oviposit until they had fed a second time. When this occurred in the summer it is thought to have been due to the fact that they had not mated, as females which remained for several weeks after engorging without depositing eggs commenced to do so very shortly after being placed with males. In the winter, however, in some cases females when with males remained for long periods without depositing, but when fed a second time began deposition. During these long preoviposition periods the females flattened considerably, the blood evidently being used by the tick to sustain life rather than in the production of eggs.

As is shown in Table IV, the greatest number of eggs deposited by any of 21 ticks observed following the first engorgement as adults was 195. The greatest number deposited by any of 21 ticks observed following the second engorgement was 237, and the greatest number deposited by a single tick following the two engorgements, 401. Following the third engorgement 245 was the largest number of eggs deposited by any of the 21 ticks observed. The greatest number of eggs deposited by any one tick following the first three engorgements was 646. The greatest number of eggs deposited by any one of the 20 ticks which were observed following the fourth engorgement was 228. Nine ticks deposited following the fifth engorgement, the greatest number of eggs deposited by an individual being 201. Although four ticks engorged the sixth time only two of these oviposited. One of these deposited 43 and the other 148 eggs. Only one tick engorged and deposited the seventh time, 47 eggs being deposited. The largest number of eggs deposited by any individual during its entire life was 874, the average number of eggs deposited per tick by the individuals observed being 537. The tick which deposited the largest number of eggs engorged five times and deposited four lots of eggs. The number of eggs deposited by any individual seems, in most cases, to be directly in proportion to its size. The average number of eggs deposited by an individual after each engorgement, based on those that oviposited, is as follows: First, 131; second, 159; third, 133; fourth, 110; fifth, 97; sixth, 95; seventh, 47. In observations previously recorded by Hunter and Hooker (1907) 274 eggs were deposited following a single engorgement. This record was based upon a tick which was adult when collected. The largest number of eggs deposited after a single engorgement by any individual observed by us was 237.

As is shown in Table IV, oviposition at summer temperatures may commence as soon as the third day after engorgement, or may be delayed for weeks if mating has not taken place. In the greater number of cases, however, it took place in from 4 to 10 days. Although the period of oviposition in one instance in which only a few eggs

were deposited lasted only three days, it usually continues during the summer months for from 6 to 10 days. After the fourth deposition, engorgement of the ticks became more difficult with each succeeding deposition. This seemed to be due largely to the weakened condition of the ticks. It therefore appears that in nature ticks seldom engorge and deposit more than five times. It seems probable, however, that if the first engorgement were made early in the spring and the ticks were engorged as soon as possible after deposition was complete, a greater number of annual depositions would occur and probably the total number of depositions would be increased.

TABLE IV.—*Oviposition of Argas miniatus.*

Date nymph molted to adult.	Date of first engorgement.	First oviposition.	
		Dates.	Number of eggs.
1. June, 1908	June 21, 22, 1908	June 29–July 10, 1908	125
2. June, 1908	....do	June 28–July 7, 1908	134
3. June–July, 1908	July 31–Aug. 1, 1908	Aug. 28–Sept. 1, 1908	49
4. July, 1908	July 27, 28, 1908	Did not deposit	......
5. July 7, 1908	....do	July 31–Aug. 8, 1908	135
6. July 4, 1908	July 29, 30, 1908	Aug. 3, 10, 1908	145
7. July, 1908	July 31–Aug. 1, 1908	Aug. 6–12, 1908	131
8. July 7, 1908	July 27, 28, 1908	Did not deposit	......
9. July, 1908	....do	Aug. 6–9, 1908	56
10. July, 1908	July 29, 30, 1908	Aug. 11–13, 1908	7
11. July 7, 1908	July 27, 28, 1908	Aug. 1–7, 1908	174
12. July 4–10, 1908	July 29, 30, 1908	Aug. 28–Sept. 3, 1908	101
13. Apr. 22, 1908	July 31–Aug. 1, 1908	Aug. 5–11, 1908	127
14. Aug. 15, 1908	Sept. 1, 2, 1908	Sept. 7–13, 1908	161
15. August, 1908	Aug. 27, 28, 1908	Sept. 2–8, 1908	195
16. ——, 1908	....do	Sept. 2–9, 1908	151
17. June 15–July 15, 1908	July 31–Aug. 1, 1908	Sept. 9–15, 1908	154
18. Aug. 17, 1908	Sept. 3, 4, 1908	Sept. 9–16, 1908	151
19. ——, 1908	Aug. 27, 28, 1908	Sept. 3–10, 1908	144
20. ——, 1908	....do	Sept. 2–9, 1908	176
21. ——, 1908	....do	....do	165

Date nymph molted to adult.	Date of second engorgement.	Second oviposition.	
		Dates.	Number of eggs.
1. June, 1908	July 29, 30, 1908	Aug. 8–13, 1908	81
2. June, 1908	July 31–Aug. 1, 1908	Aug. 5–11, 1908	111
3. June–July, 1908	Sept. 3, 4, 1908	Sept. 7–14, 1908	146
4. July, 1908	Aug. 21, 22, 1908	Sept. 10–17, 1908	83
5. July 7, 1908	Aug. 14, 15, 1908	Aug. 18–27, 1908	170
6. July 4, 1908	....do	Aug. 18–25, 1908	172
7. July, 1908	Aug. 21, 22, 1908	Aug. 27–Sept. 2, 1908	154
8. July 7, 1908	Aug. 25, 26, 1908	Sept. 15, 1908	156
9. July, 1908	Aug. 14, 15, 1908	Aug. 20–28, 1908	137
10. July, 1908	Aug. 21, 22, 1908	Aug. 28–Sept 5, 1908	137
11. July 7, 1908	Aug. 14, 15, 1908	Aug. 18–27, 1908	227
12. July 4–10, 1908	Sept. 7, 8, 1908	Sept. 12–15, 1908	167
13. Apr. 22, 1908	Aug. 14, 15, 1908	Aug. 17–28, 1908	163
14. Aug. 15, 1908	Sept. 14, 15, 1908	Sept. 20–Oct. 4, 1908	219
15. August, 1908	Sept. 11, 12, 1908	Sept. 16–24, 1908	193
16. ——, 1908	....do	Sept. 15–22, 1908	89
17. June 15–July 15, 1908	Sept. 20, 21, 1908	Sept. 26–Oct. 14, 1908	195
18. Aug. 17, 1908	....do	Sept. 25–Oct. 19, 1908	237
19. ——, 1908	Sept. 14, 15, 1908	Sept. 20–Oct. 3, 1908	181
20. ——, 1908	Sept. 11, 12, 1908	Oct. 8–22, 1908	145
21. ——, 1908	....do	Sept. 16–24, 1908	182

TABLE IV.—*Oviposition of Argas miniatus*—Continued.

Date nymph molted to adult.	Date of third engorgement.	Third oviposition.	
		Dates.	Number of eggs.
1. June, 1908	Aug. 14, 15, 1908	Aug. 17-24, 1908	111
2. June, 1908	do	Aug. 18-26, 1908	163
3. June-July, 1908	do	Sept. 20-27, 1908	153
4. July, 1908	Sept. 20, 21, 1908	Sept. 25-Oct. 8, 1908	116
5. July 7, 1908	Aug. 30, 31, 1908	Sept. 3-12, 1908	172
6. July 4, 1908	do	Sept. 4-10, 1908	160
7. July, 1908	Sept. 3, 4, 1908	Sept. 7-14, 1908	243
8. July 7, 1908	Sept. 27, 28, 1908	Oct. 14-19, 1908	76
9. July, 1908	Aug. 30, 31, 1908	Sept. 7-14, 1908	139
10. July, 1908	Sept. 7, 8, 1908	Sept. 13-15, 1908	122
11. July 7, 1908	Aug. 30, 31, 1908	Sept. 3-11, 1908	245
12. July 4-10, 1908	Sept. 21, 22, 1908	Sept. 26-Oct. 8, 1908	177
13. Apr. 22, 1908	Aug. 30, 31, 1908	Sept. 5-11, 1908	50
14. Aug. 15, 1908	Oct. 5, 6, 1908	Oct. 15-Nov. 9, 1908	227
15. August, 1908	Sept. 28, 29, 1908	Feb. 19-March, 1909	118
16. ——, 1908	do	Oct. 4, 1908	4
17. June 15-July 15, 1908	Oct. 27, 28, 1908	Nov. 14?-Dec. 11, 1908	149
18. Aug. 17, 1908	do	Did not deposit	......
19. ——, 1908	Oct. 5, 6, 1908	Mar. 15-Apr. 5, 1909	102
20. ——, 1908	Oct. 29, 30, 1908	Mar. 2-21, 1909	25
21. ——, 1908	Sept. 27, 28, 1908	Oct. 6-20, 1908	106

Date nymph molted to adult.	Date of fourth engorgement.	Fourth oviposition.	
		Dates.	Number of eggs.
1. June, 1908	Aug. 30, 31, 1908	Sept. 8-15, 1908	97
2. June, 1908	Sept, 1, 2, 1908	Sept. 7-13, 1908	126
3. June-July, 1908	Oct. 6-8, 1908	Feb. 23-Mar. 20, 1909	90
4. July, 1908	Oct. 27, 28, 1908	Feb. ?-23, 1909	72
5. July 7, 1908	Sept. 14, 15, 1908	Sept. 20-Oct. 5, 1908	82
6. July 4, 1908	Sept. 11, 12, 1908	Sept. 17-25, 1908	167
7. July, 1908	Sept. 21, 22, 1908	Sept. 27-Oct. 17, 1908	182
8. July 7, 1908	Did not engorge		......
9. July, 1908	Sept. 14, 15, 1908	Sept. 18-Oct. 6, 1908	81
10. July, 1908	Sept. 28, 29, 1908	Oct. 8-22, 1908	114
11. July 7, 1908	Sept. 14, 15, 1908	Sept. 19-30, 1908	228
12. July 4-10, 1908	Oct. 27, 28, 1908	Feb. 21-Mar. 6, 1909	72
13. Apr. 22, 1908	Sept. 14, 15, 1908	Sept. 19, 20, 1908	11
14. Aug. 15, 1908	Dec. 5, 6, 1908	Did not deposit	......
15. August, 1908	Apr. 16, 17, 1909	Apr. 26-May 9, 1909	176
16. ——, 1908	Oct. 27, 28, 1908	Did not deposit	......
18. Aug. 17, 1908	June 8, 9, 1909	Died June 29, 1909	......
19. ——, 1908	Apr. 16, 17, 1909	Apr. 24-May 24, 1909	60
20. ——, 1908	June 8, 9, 1909	Did not deposit	......
21. ——, 1908	Oct. 28, 29, 1908	Feb. 2-Mar. 8, 1909	97

TABLE IV.—*Oviposition of Argas miniatus*—Continued.

Date nymph molted to adult.	Date of fifth engorgement.	Fifth oviposition.	
		Dates.	Number of eggs.
1. June, 1908	Sept. 20, 21, 1908	Sept. 25–Oct. 17, 1908	135
2. June, 1908	Sept. 14, 15, 1908	Sept. 23–Oct. 17, 1908	61
3. June–July, 1908	Apr. 22, 23, 1909	May 11–16, 1909	72
4. July, 1908	Apr. 16, 17, 1909	May 5–14, 1909	85
5. July 7, 1908	Oct. 27, 28, 1908		
6. July 4, 1908	Sept. 27, 28, 1908	Apr. 5, 1909	11
7. July, 1908	Oct. 27, 28, 1908	Did not deposit	
8. July 7, 1908	Did not engorge	Crushed Apr. 24, 1909	
9. July, 1908	Oct. 27, 28, 1908	Did not deposit	
10. July, 1908	do	Lost	
11. July 7, 1908	Did not engorge		
12. July 4–10, 1908	Apr. 16, 17, 1909	Apr. 24–May 14, 1909	155
13. Apr. 22, 1908	Oct. 6, 7, 1908	Did not deposit	
14. Aug. 15, 1908	June 12, 13, 1909	June 21–27, 1909	114
16. ——, 1908	Aug. 25, 26, 1909		
19. ——, 1908	Aug. 24, 25, 1909	Aug. 20–Sept. 4, 1909	201
20. ——, 1908	Oct. 28, 29, 1909	Did not deposit	
21. ——, 1908	Sept. 16, 17, 1909	Apr. 28–May 12, 1909	41

Date nymph molted to adult.	Date of sixth engorgement.	Sixth oviposition.	
		Dates.	Number of eggs.
2. June, 1908	Oct. 27, 28, 1908	Died July 13, 1909	
3. June–July, 1908	Did not engorge	Died July 15, 1909	
4. July, 1908		Died July 13, 1909	
5. July 7, 1908	Oct. 28, 29, 1908	Killed Dec. 5, 1908	
6. July 4, 1908	Did not engorge	Died June 13, 1909	
7. July, 1908	Nov. 19, 20, 1909	Did not deposit	
11. July 7, 1908	Did not engorge, Oct. 27, 28, 1908.	Died Nov. 21, 1908	
14. Aug. 15, 1908		Died Aug. 23, 1909	
16. ——, 1908		Died Feb. 20, 1910	
19. ——, 1908	Sept. 20, 21, 1909	Oct. 2–5, 1909	43
21. ——, 1908	Aug. 25, 26, 1909	Aug. ?–Sept. 6, 1909	148

Date nymph molted to adult.	Date of seventh engorgement, or death of tick.	Seventh oviposition.		Total.		
		Dates.	Number of eggs.	Number of engorgements.	Number of depositions.	Number of eggs.
1. June, 1908	Died Oct. 28, 1908			5	5	549
2. June, 1908	Died July 13, 1909			6	5	595
3. June–July, 1908	Died July 15, 1909			5	5	510
4. July, 1908	Died July 13, 1909			5	4	356
5. July 7, 1908	Killed Dec. 5, 1908			6	4	559
6. July 4, 1908	Died June 13, 1909			5	5	655
7. July, 1908	Died Dec. 10, 1909			6	4	710
8. July 7, 1908	Crushed Apr. 24, 1909			5	2	252
9. July, 1908	Lost June 10, 1909			5	4	413
10. July, 1908	Lost			5	4	380
11. July 7, 1908	Died Nov. 21, 1908			5	4	874
12. July 4–10, 1908	Died before Aug. 4, 1909			5	5	672
13. Apr. 22, 1908	Died July 13, 1909			5	4	351
14. Aug. 15, 1908	Died Aug. 23, 1909			5	4	721
15. August, 1908	Died July 16, 1909			4	4	682
16. ——, 1908	Died Feb. 20, 1910			5	3	244
17. June 15–July 15, 1908	Died Jan. 5, 1909			3	3	498
18. Aug. 17, 1908	Died June 20, 1909			4	2	388
19. ——, 1908	Mar. 8, 9, 1910	Did not deposit [1]		7	6	731
20. ——, 1908	Died Mar. 30, 1910			5	3	346
21. ——, 1908	Sept. 20, 21, 1909	Oct. 2–8, 1909 [2]	47	7	7	786

[1] Died Apr. 4, 1910. [2] Died Dec. 10, 1909.

The period required for the incubation of eggs in August was found to be as short as 10 days, at least 437° F. of effective temperature being required for incubation. Eggs kept in an incubator at a mean temperature of 89.8° F. hatched on the ninth day, an effective temperature of 421° F. accumulating. Rohr states that eggs kept at 35° C. (95° F.) hatch in from 8 to 11 days.

TABLE V.—*Incubation period of Argas miniatus.*

Eggs deposited.	Hatching.	Minimum incubation period.	Temperature during incubation. Maximum.	Minimum.	Average daily mean.	Total effective.
		Days.	*° F.*	*° F.*	*° F.*	*° F.*
June 29, 1908	July 11, 1908	13	93.5	70.5	81.44	499.75
July 1, 1908	July 14, 1908	14	93.5	70.5	81.98	545.75
July 9, 1908	July 21, 1908	13	94.0	74.0	83.79	530.25
July 31, 1908	Aug. 12, 1908	13	99.0	73.0	86.15	561.00
Aug. 5, 1908	Aug. 15, 1908	11	99.0	73.0	86.59	479.50
Aug. 7, 1908	Aug. 16, 1908	10	99.0	73.0	86.75	437.50
Aug. 10, 1908	Aug. 19, 1908	10	96.5	75.0	87.15	441.50
Aug. 18, 1908	Aug. 30, 1908	13	93.0	75.5	83.48	526.25
Aug. 24, 1908	Sept. 5, 1908	13	94.5	75.0	83.40	525.25
Aug. 31, 1908	Sept. 11, 1908	12	97.5	74.5	84.41	496.95
Sept. 3, 1908	Sept. 15, 1908	13	97.5	74.5	83.49	526.45
Sept. 30, 1908	Oct. 28, 1908	29	87.0	48.0	69.00	755.00
Oct. 7, 1908	Nov. 15, 1908	40	87.0	34.0	65.20	887.00
Oct. 8, 1908	Nov. 7, 1908	31	87.0	45.0	67.00	743.00
Nov. 7, 1908	Jan. 22, 1909	77	82.0	17.0	59.50	1,141.00+
Nov. 9, 1908	Feb. 23, 1909	107	85.0	17.0	59.50	1,582.00+
Nov. 23, 1908	....do	93	85.0	17.0	58.50	1,339.00+
May 1, 1909	May 20, 1909	20	95.0	51.0	76.50	671.00
Sept. 20, 1909	Oct. 15, 1909	26	95.0	52.0	74.50	860.00
Oct. 2, 1909	Oct. 24, 1909	23	94.0	52.0	73.10	693.00
Oct. 6, 1909	Nov. 3, 1909	29	92.0	51.0	71.60	831.00

The larva (Tables VI, VII, VIII).—Seed ticks kept in pill boxes in the laboratory at an average daily mean temperature of 61.9° F. have been found to live as long as 164 days. During midsummer the longevity is about two months.

TABLE VI.—*Larval longevity of Argas miniatus.*

Date hatching began.	Date all larvæ dead.	Days from hatching to death.	Date hatching began.	Date all larvæ dead.	Days from hatching to death.
Aug. 9, 1908	Oct. 20, 1908	62	Nov. 2, 1908	Mar. 22, 1909	140
Sept. 8, 1908	Dec. 25, 1908	108	Nov. 9, 1908	Mar. 27, 1909	137
Sept. 25, 1908	Jan. 24, 1909	121	Dec. 1, 1908	Mar. 17, 1909	105
Oct. 15, 1908	Feb. 24, 1909	132	May 18, 1909	July 15, 1909	77
Oct. 17, 1908	Mar. 30, 1909	164	May 24, 1909	July 27, 1909	64
Oct. 21, 1908	Mar. 27, 1909	147			

At a temperature varying from 18° C. (64.4° F.) to 27° C. (80.6° F.) Rohr has found individual larvæ to live as long as 65 days.

Ordinarily larvæ do not commence to drop from the host until the fourth day following attachment, although one may occasionally leave the host a day sooner. All the larvæ which we observed engorged

and left the host by the tenth day following attachment. The observations of Rohr (1909) on the dropping of the larvæ do not agree exactly with ours. According to his records in Brazil the larvæ may commence to drop as soon as the second day following attachment, the greater number leaving the host on the third and fourth days and all leaving the host before the eighth day.

TABLE VII.—*Engorgement of larvæ of Argas miniatus.*

Date larvæ were applied.	Number of larvæ dropped engorged—days following attachment.[1]								Total number dropped.
	3½	4	5	6	7	8	9	10	
Aug. 12, 1907, 5.00 p. m.	0	0	17	12	4	1	0	0	34
Aug. 19, 1907, 5.00 p. m.	0	1	9	6	4	1	0	0	21
Oct. 13, 1907, 11.00 a. m.	0	0	0	1	1	0	0	0	2
June 30, 1908, 8.00 p. m.	0	0	0	48	14	2	0	0	64
Aug. 22, 1908, 10.00 p. m.	0	0	18	12	2	0	0	0	32
Sept. 20, 1909, 10.30 p. m.	1	36	17	19	14	5	2	1	95
Do	0	17	4	3	3	0	0	0	27
Oct. 22, 1909, 10.00 p. m.	0	0	0	12	17	10	9	2	50

[1] In this and all subsequent tables in which this arrangement is followed, the top line of figures represents the number of days following attachment or dropping and the figures in the columns beneath represent the number of ticks dropped, the number molted, or the number of eggs deposited on the respective days following attachment or dropping as the case may be.

In a test to determine the relative susceptibility of individual fowls to tick attack, a Leghorn pullet, a Barred Plymouth Rock pullet, a setting hen (part Leghorn) and a sick hen (part Leghorn) were placed in a cage and infested with larvæ. An effort was made to place about the same number of larvæ on each individual and a number were left free in the cage with the fowls. The following number of ticks dropped from the different individuals: Leghorn pullet 26, Plymouth Rock pullet 27, setting hen 95, and sick hen 13. The sick hen died on the sixth day after infestation. A second infestation of the three remaining fowls was made on a later date. At this time the setting hen was no longer inclined to set. As a result of this infestation, about the same number of larvæ were engorged on each of the three fowls. The experiment tends to indicate that there is no marked variation in the susceptibility of individuals of different breeds. It appears to show, however, that on setting hens, which are quiet at the time of infestation and afterwards, the number of larvæ which develop is greatly increased.

Up to within a few hours of dropping, the larvæ are globular in shape, but at this time they flatten and assume the typical Argas shape, which permits the tick to crawl rapidly and secrete itself before being discovered and devoured by its natural enemies. Barring accident the engorged larvæ drop only at night when their host is upon the roost. The larval is the only stage in which the species remains upon the host for any length of time. Advantage can be taken of this fact in preventing its dissemination.

Seed ticks have been observed to gather on the ventral surface of adult ticks and it is thought possible that they are at times assisted in finding hosts by clinging to the older ones.

In August at a mean temperature of 83° F. molting commenced as soon as the fourth day, an effective temperature of 160° F. being required. In one case a molting period of 32 days was observed. In this instance the individual was undoubtedly very weak as it did not succeed in freeing itself from the exuvium without assistance. Rohr states that with a temperature of 35° C. (95° F.) molting takes place in 4 or 5 days.

TABLE VIII.—*Molting of larvæ (first ecdysis) of Argas miniatus.*

Date engorged larvæ dropped—night of.	Number.	Larvæ molted—days following dropping.															Temperature from dropping to date first tick molted.		
		4	5	6	7	8	9	10	11	12	13	14	16	17	32	Number molted.	Maximum.	Minimum.	Average daily mean.
																	°F.	°F.	°F.
Aug. 16, 17, 1907	14	0	10	1	0	0	0	1	0	0	0	0	0	0	0	12	......	......	......
Aug. 17, 18, 1907	10	0	5	3	0	0	0	0	0	0	0	0	0	0	0	8	......	......	......
Aug. 18, 19, 1907	4	1	0	1	0	1	0	0	0	0	0	0	0	0	0	3	......	......	......
Aug. 23, 24, 1907	9	0	2	4	2	0	0	0	0	0	0	0	0	0	0	8	......	......	......
Aug. 24, 25, 1907	6	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	......	......	......
Oct. 19, 20, 1907	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	......	......	......
Apr. 23, 24, 1908	2	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	83.0	47.0	67.90
July 5, 6, 1908	48	0	31	5	4	1	0	2	0	0	0	0	0	0	0	43	93.0	75.5	83.00
July 6, 7, 1908	14	1	8	3	0	0	0	0	0	0	0	0	0	0	0	12	93.0	75.5	83.00
July 7, 8, 1908	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2	93.5	75.5	83.79
Aug. 26, 27, 1908	16	0	4	3	4	0	0	0	0	0	0	0	0	0	0	11	89.5	75.5	83.29
Aug. 27, 28, 1908	12	0	11	1	0	0	0	0	0	0	0	0	0	0	0	12	89.5	75.5	83.29
Aug. 28, 29, 1908	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2	89.5	75.5	83.42
Sept. 24, 25, 1909	70	0	0	0	0	3	36	10	1	0	0	0	0	0	0	50	91.0	56.0	72.9
Sept. 25, 26, 1909	33	0	0	0	0	8	19	3	0	0	0	0	0	0	0	30	92.0	56.0	73.7
Sept. 26, 27, 1909	28	0	0	0	3	14	1	3	1	0	0	0	0	0	1	23	92.0	56.0	74.1
Sept. 27, 28, 1909	20	0	0	4	12	4	0	0	0	0	0	0	0	0	0	20	92.0	56.0	75.0
Oct. 27, 28, 1909	37	0	0	0	0	0	0	12	14	7	0	2	0	0	0	35	84.5	55.0	72.5
Oct. 28, 29, 1909	32	0	0	0	0	0	3	14	10	0	0	0	0	2	0	29	84.0	55.0	71.8
Oct. 29, 30, 1909	10	0	0	0	0	0	0	5	0	3	2	0	0	0	0	10	84.0	55.0	71.7
Total	370	...	...	...	...	...	...	...	...	...	...	...	...	...	...	316	.....	.....	......

The nymph (Table IX).—Rohr shows that at a mean temperature of 15° C. (59° F.) first and second stage nymphs may live as long as two years, while at a temperature varying from 17° C. (62.6° F.) to 33° C. (91.4° F.) all under observation were dead in 469 days.

This species appears to vary in the number of molts that it passes as a nymph. As previously shown by Hooker (1909), there is a third nymphal molt in many of the individuals which have been reared. In view of the fact that the extra molt could not be traced to a difference in the sexes, the food supply, or the climatic conditions, it is thought that it might have been due to an adaptation that the species is undergoing, as the fourth ecdysis requires an extra engorgement before reproduction can commence. The nymphs, like the adults, require only a comparatively few minutes for engorgement.

Nuttall and Warburton found that two-thirds of the nymphs and adults engorged within 30 minutes. In observations of 148 nymphs these workers found 120 minutes to be the longest period required for engorgement.

First-stage nymph (Table IX).—The longevity of first-stage nymphs was found in one instance to be as great as 269 days. Of 29 first-stage nymphs, which molted between July 28 and 31, 1907, and were kept in pill boxes, 14 were found to be alive on October 12, 5 having escaped and 12 being dead. Of the 14 remaining alive 3 escaped, the others succumbing as follows: Two on November 14, 1 on November 21, 1 on January 1, 1 on February 18, 3 between March 27 and April 16, and the last one on April 25, 1908. A large number of first-stage nymphs which molted from larvæ October 3–8, 1909, were all dead by April 22, 1910, thus living slightly over 6 months. The greatest longevity recorded in a lot of 88 first-stage nymphs which molted from larvæ November 7–12, 1909, was slightly over 9 months.

TABLE No. IX.—*Molting of nymphal stages of Argas miniatus.*

[♂=Male. ♀=Female. ⊕=Nymph.]

MOLTING OF FIRST STAGE (SECOND ECDYSIS).

Date engorged first-stage nymphs dropped.	Number.	First-stage nymphs molted—days following dropping (engorgement).																		Temperature from dropping to date first tick molted.		
		7	8	9	10	11	12	13	14	15	16	17	20	23	24	25	26	28	Number molted.	Maximum.	Minimum.	Average daily mean.
																				°F.	°F	°F.
Aug. 28, 29, 1907	11	0	2	2	5	1	1	0	0	0	0	0	0	0	0	0	0	0	11	......	......	......
Sept. 1, 2, 1907	10	0	2	1	2	2	3	0	0	0	0	0	0	0	0	0	0	0	10	......	......	......
Apr. 23, 24, 1908	......	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	4	1	11	86.0	47.0	69.3
May 20, 21, 1908	......	0	0	0	0	2	4	4	3	1	1	3	0	0	0	0	0	0	18	86.0	68.0	77.5
July 20, 21, 1908	37	18	13	0	4	0	1	0	0	0	0	1	0	0	0	0	0	0	37	95.0	76.5	84.6

MOLTING OF SECOND STAGE (THIRD ECDYSIS)

Date second-stage nymphs engorged.	Number.	Second-stage nymphs molted—days following dropping (engorgement).																
		11	12	13	14	15	16	17	18	19	20	24	26	30	33	36	37	43
Oct. 3, 4, 1907	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 24, 25, 1908	......	0	0	0	0	0	0	0	0	0	0	0	1♀	1♂ 1♀	1♂	1♂	1	2♂
July 31, Aug. 1, 1908	......	3♂	3♂ 1♀	1♂ 5♀	1♂ 2♀	0	1♀	0	0	0	0	1♀	0	0	0	0	0	0
Aug. 4, 5, 1908	18	0	0	3⊕	1♂ 5♀	1♂ 1♀	1♂ 1♀	1♂ 1⊕	0 1♀	0 1♂	0	0	0	0	0	0	0	0
Aug. 6, 7, 1908	7	0	0	0	0	1⊕	3♂ 1♀	1♂	0	0	1♂	0	0	0	0	0	0	0

TABLE No. IX.—*Molting of nymphal stages of Argas miniatus*—Continued.

MOLTING OF SECOND STAGE (THIRD ECDYSIS)—Continued.

Date second-stage nymphs engorged.	Number.	Second-stage nymphs molted—days following dropping (engorgement).									Temperature from dropping to date first tick molted.		
		177	183	184	185	195	199	Number molted.			Maximum.	Minimum.	Average daily mean.
											°F.	°F.	°F.
Oct. 3, 4, 1907	9	1♂	2♀	1⊕	1⊕	1♂	0	2♂	2♀	2⊕	....	....	....
Apr. 24, 25, 1908	......	0	0	0	0	0	0	...	...	...	87.0	47.0	70.91
July 31, Aug. 1, 1908	......	0	0	0	0	0	0	8♂	10♀	0⊕	99.0	73.0	86.06
Aug. 4, 5, 1908	18	0	0	0	0	0	0	5♂	8♀	4⊕	99.0	73.0	86.61
Aug. 6, 7, 1908	7	0	0	0	0	0	0	5♂	1♀	1⊕	99.0	73.0	86.64

MOLTING OF THIRD STAGE (FOURTH ECDYSIS).

Date third-stage nymphs engorged.	Number.	Third-stage nymphs molted—days following dropping (engorgement).					Temperature from dropping to date first tick molted.		
		9	10	11	12	Number molted.	Maximum.	Minimum.	Average daily mean.
							°F.	°F.	°F.
June 20, 21, 1908	2	0	0	0	2♀	2	89.5	71.0	80.73
Aug. 28, 29, 1908	5	1♀	1♂	2♀	1♀	5	97.5	75.0	83.98

Observations are recorded by Nuttall and Warburton, who found all of 14 first-stage nymphs of this species to engorge and drop within 35 minutes.

Second-stage nymph (Table IX).—In our experiments second-stage nymphs lived longer than those in the first stage. Of two which molted July 31, 1907, and were kept in a pill box, one died July 30, 1908. One nymph which molted from the first stage on June 15, 1908, was still alive February 23, 1909, when it was lost, thus having a longevity of at least 253 days. The last individual of a large number of first-stage nymphs which molted to this stage October 24–31, 1909, died January 12, 1911, thus showing a longevity of 445 days. The last tick of a lot of 12 which molted from the first stage November 1, 1909, died March 25, 1911, having lived 509 days, or about 1 year and 5 months. At a mean temperature of 86° F. in August, nymphs of the second stage molted as soon as the eleventh day following engorgement, 473° F. of effective temperature being required.

Third-stage nymph (Table IX).—We have found that about one-seventh of the individuals reared under similar conditions pass a third nymphal molt—i. e., of 49 individuals reared from seed ticks to adults 7 passed a third nymphal molt. Six of these after molting proved to be females and one a male.

In August, at a mean temperature of 84° F., molting commenced as soon as the ninth day following dropping, an effective temperature of 369° F. being required.

The adult[1] (Table X).—The males and females may be readily distinguished by the shape of the genital orifice, that of the former being crescent shaped while in the latter it is merely a transverse slit.

The longevity of the adults is surprisingly great. From a lot of ticks collected March 24, 1906, which were kept confined in a vial with a cork stopper, one lived until September 3, 1907, a period of 17 months. In two miscellaneous lots of some 50 or more ticks collected May 12, 1906, and kept in large vials with paper strips, the last individual died about October 12, 1908, having lived for 2 years and 5 months. Some individuals in nearly all of a large number of lots of collected ticks have been found to live more than one year.

Females lived from 5 to 13 months when engorged soon after they had molted to the adult stage and immediately after each deposition. One specimen, which was engorged three times, lived 18 months, depositing 244 eggs in the meantime.

The longevity of adults which have not fed after molting appears to be slightly less than when some food has been taken. One individual, which molted to an adult August 16, 1908, was still alive May 27, 1910, having lived over 21½ months. However, most of the specimens observed died between 4 and 12 months after molting. Laboulbène (1881) has reported the fowl tick to live (unfed) for more than three years.

Fertilization is accomplished by means of a spermatophore, which is deposited by the male at the genital aperture of the female, following the introduction of the hypostome of the male into the genital opening of the female. The act of copulation is described in somewhat greater detail on page 30.

The adults engorge repeatedly and oviposition follows each engorgement, with few exceptions. Thus, as shown in Table IV, we have found females to engorge as many as seven times, each engorgement being followed by the deposition of eggs. Lounsbury (1903a) has found females to engorge as many as seven times and to deposit following six engorgements. As has been stated, Nuttall and Warburton found that two-thirds of the nymphs and adults engorge within 30 minutes. We have not determined the exact time required for engorgement. However, in one case 38 per cent of a large number of adults applied to a fowl had dropped engorged when examination was made an hour and a half later. Usually engorgement takes place at night, but when fowls are exposed to their attack in dark

[1] Our system of numbering adult ticks of this species, in order that they might readily be identified after engorging, consisted in the docking of a part of one or more legs. This apparently has no ill effect upon these ticks.

places, such as on nests, engorgement may take place during the daytime. In warm weather oviposition is usually completed in from 10 to 14 days and engorgement takes place again as soon as a host is found.

The dimensions of females prior to engorgement is increased slightly with each deposition. The average size of an individual taken after successive engorgements does not, however, seem to increase noticeably after the tick has become replete the second time. The size of males also appears to increase slightly with successive engorgements. The maximum, minimum, and average length, width, and thickness of females, the deposition of which is recorded in Table IV, before and after each engorgement, is given in Table X.

TABLE X.—*Size of females of Argas miniatus before and after successive engorgements.*

Number of engorgement.	Number of ticks measured.	Size before engorging.		
		Maximum.	Minimum.	Average.
		Mm.	*Mm.*	*Mm.*
First	9	7 by 5	5 by 3.5	6.4 by 4.1.
Second	11	7.5 by 4.75	6.5 by 3.75	7.1 by 4.4
Third	18	8 by 5.5	7 by 4	7.4 by 4.5.
Fourth	19	8 by 5.5	6.1 by 4.3	7.5 by 4.6.
Fifth	14	8.8 by 5.5 by 1.6	6.9 by 4.2 by 1.3	7.7 by 4.8 by 1.5.
Sixth	8	9.6 by 5.9 by 2.3	7 by 4.3 by 1.2	8.1 by 4.9 by 1.7.
Seventh	2	8.6 by 5.1 by 2.1	7.4 by 5.1 by 1.3	8 by 5.1 by 1.7.

Number of engorgement.	Number of ticks measured.	Size after engorging.		
		Maximum.	Minimum.	Average.
		Mm.	*Mm.*	*Mm.*
First	19	10 by 6 by 3.5	6 by 4 by 2	8.8 by 5.4 by 2.7.
Second	20	10.5 by 6.5 by 3.5	8 by 5 by 2.5	9.5 by 5.6 by 2.9.
Third	21	11 by 6 by 3.5	8 by 4.2 by 2.25	9.6 by 5.6 by 2.7.
Fourth	17	11 by 6.5 by 3	8.5 by 4.5	9.4 by 5.5 by 2.6.
Fifth	14	10.3 by 6 by 2.7	8 by 4.7 by 1.9	9.2 by 5.5 by 2.5.
Sixth	4	10.2 by 6.5 by 3	9.4 by 5.7 by 2.4	9.8 by 5.9 by 2.9.
Seventh	2	9.9 by 5.9 by 2.6	9.3 by 5.5 by 3	9.6 by 5.7 by 2.8.

LIFE CYCLE.

This tick as a larva attaches to a fowl, preferably beneath the wings, remains attached usually for 5 or 6 days, becomes engorged, and, a few hours before dropping, flattens out and assumes the typical Argas shape. The larvæ drop at night, at a time when the fowl host is upon the roost and where they will be near the host when ready to engorge again. In summer a period of 4 or more days passes before the engorged larvæ molt and the 8-legged nymphs appear. The second engorgement, which occurs at night, lasts only a few hours at the most and is followed in summer by a period of 7 days or more before the second molt. A third engorgement occurs at night and 11 days or more pass before any of the ticks molt and appear as adults. In about one-seventh of the individuals there is an extra nymphal or

fourth molt before arriving at the adult stage, 9 or more days (369° F. of effective temperature) being required for the ecdysis. The first adult engorgement then takes place, and following copulation eggs are deposited. Unlike the ticks of other genera, with the exception of some species of Ornithodoros, these ticks engorge a number of times as adults, and each engorgement is usually followed by oviposition. The eggs may hatch in summer as soon as 10 days, 437° F. of effective temperature being required for their incubation.

ECONOMIC IMPORTANCE.

In parts of the southern United States this tick is the most important ectoparasite of fowls, though perhaps surpassed in some localities by some of the insect pests. It is frequently referred to as the "blue bug" because of the bluish color when engorged with blood. In Brazil, Martinique, India, Soudan, Transcaucasia, and South Australia a disease of fowls known as spirochetosis is transmitted by this species. The presence of this disease in the United States has not been demonstrated, but on account of the losses due to the tick as a parasite in certain sections of Texas, poultry raisers in some cases have entirely abandoned the business. It has been found that the spirochete virus when imbibed will remain virulent within the tick during a period of six months fasting. Dodd (1910), who has recently studied the disease in Australia, reports that in one instance a fowl which was bitten by ticks that had fasted for 7 months and 6 days died with symptoms of chronic spirochetosis.

Lounsbury, who has permitted specimens of *Argas miniatus* and *Ornithodoros savignyi* to feed upon his arm, concludes that while they may be productive of considerable irritation and their penetration serve as the entering point for some of the abscess-forming bacteria, as may be said of all the ticks, yet otherwise their direct effect is harmless. Nuttall and Strickland (1908) have found that the salivary glands and intestines of the fowl tick contain anticoagulin, but no hemolysin.

NATURAL CONTROL.

The habits of this tick are such as to protect it from natural enemies, although it is undoubtedly fed upon by rats and mice and devoured by fowls. To determine the effect of water upon it, 25 larvæ which had hatched on September 1 were submerged on September 9 and kept so for 17½ hours, during all of which time they remained inactive. When removed from the water all proved to be alive and were again submerged and left until a total period of 65½ hours had elapsed. One survived and lived for about two weeks following removal from the water. Thirteen larvæ which had hatched several days previous were submerged on September 12 for a period of 50 hours and none survived.

ARTIFICIAL CONTROL.

It is not our intention to go into detail regarding remedial measures at this time, as a circular is being prepared from which the information may be obtained.

The larvæ, which may remain attached to the fowl as long as 8 days before dropping, are almost certain to be carried from one locality to another with the fowls. In order to prevent such dissemination, fowls should be isolated in a tick-free cage or inclosure for 10 days before being transported to a tick-free house, as by the end of the period all will have dropped from the fowl. As it is the habit of ticks to crawl into cracks and crevices, it should be borne in mind that they may be conveyed from one point to another in shipping cages unless great care is taken. It is thought quite probable that the larvæ may be disseminated by pigeons and small birds.

The species is resistant to insecticides to a remarkable degree. When once this tick has become established in a poultry house, it is difficult to eradicate it entirely except through the use of fire. Much, however, can be accomplished by the frequent use of kerosene, crude petroleum, or creosote. Frequent and thorough cleaning of the poultry house and the application of one of these substances to the cracks and crevices will greatly assist in keeping the pest down.

Several plans for roosts which will prevent the ticks from gaining access to fowls at night have been suggested by Lounsbury (1903a) and others. In practice it has been found that roosts and nests suspended from the roof with baling wire will largely protect the fowls from tick attack. It is also important that the ticks be furnished with the least number of hiding places possible.

Genus ORNITHODOROS Koch.

Only one of the four species of the genus Ornithodoros which occur in the United States has been studied.[1] This species, *Ornithodoros megnini*, appears to be the only one of the four that occurs in sufficient numbers to be of particular economic importance. Nuttall and Warburton in their monograph of the Argasidæ have recognized 11 well established and 3 doubtful species as belonging to the genus. One of these, *O. moubata,* is of special importance, as it transmits human tick fever in Africa.

THE SPINOSE EAR TICK.

Ornithodoros megnini (Dugès).

The common name of *Ornithodoros megnini* is taken from its habit of infesting the ears and from the characteristic spines on the body of the nymph.

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[1] As previously stated studies of two other species (*O. turicata* and *O. talaje*) are now under way.

DESCRIPTIVE.

Adult (Pl. IV, figs. 6–9).—Female 5 by 3.5 by 2.5 mm. to 10 by 6 by 3.5 mm. Male usually somewhat smaller than the female. The adults are grayish to dark brown in color.

Nymph (Pl. IV, figs. 2–5).—Unengorged, 2.25 by 1.5 mm. to 3 by 2 mm.; engorged, 7 by 4 by 2 mm. to 8 by 5 by 3 mm. The body of nymphs as they emerge from the larval skin have a blood-red color extending to the first two segments of the legs; otherwise they are a pearly white. Soon, however, they turn to a reddish brown.

Larva (Pl. IV, fig. 1).—Unengorged, about 0.55 by 0.30 mm.; engorged, 3 by 2 mm. to 4 by 2.5 mm. The seed ticks are dark gray in color, turning to a pink, then to a whitish color as they engorge.

Egg.—Spherical, dark brown, shining, smooth. The average size of 10 specimens measured was 0.480 by 0.456 mm.

HOST RELATIONSHIP.

It is the habit of this tick to attach in the ears of the host, deep down in the folds of the concha and frequently in the external meatus. This habit appears to be more or less of an adaptation for protection, since they can not be removed by the host, or picked off by birds, and are not exposed to the attack of parasites.

The species was described from specimens taken from the ears of Mexican horses. Though collected more frequently from cattle than from any other host, it appears to attach to any of the larger mammals with which it comes in contact. In collections made in Texas and neighboring States by agents of the Bureau of Entomology up to January, 1911, 53 lots were from cattle, 11 from horses, 10 from dogs, 8 from cats, 3 from asses, 2 from mules, 2 from man, and 1 each from sheep and hog. It has been taken by Mr. H. S. Barber in California from the black-tailed deer.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 2.)

This tick was originally described by Dugès from Guanajuato, Mex., where it is said to be very abundant. We have found it to be a very important tick in certain parts of Texas, New Mexico, Arizona, California, and Mexico. Owing to the fact that it remains attached for long periods it may be widely disseminated on cattle, horses, and other animals shipped from an infested district. This fact doubtless accounts for some of the records from northern States. Up to the present time we have authentic records of its collection from the States of Kentucky, Iowa, Nebraska, Kansas, Oklahoma, Oregon, New Mexico, Idaho, Nevada, Arizona, California, Colorado, Texas, Louisiana, and Utah. The species was found in abundance by

Bishopp at Monclova, Durango, Torreon, Aguas Calientes, and Monterey, Mex. It is undoubtedly present throughout the greater part of Mexico and may be found to be distributed through Central and parts of South America when systematic collection is undertaken, as

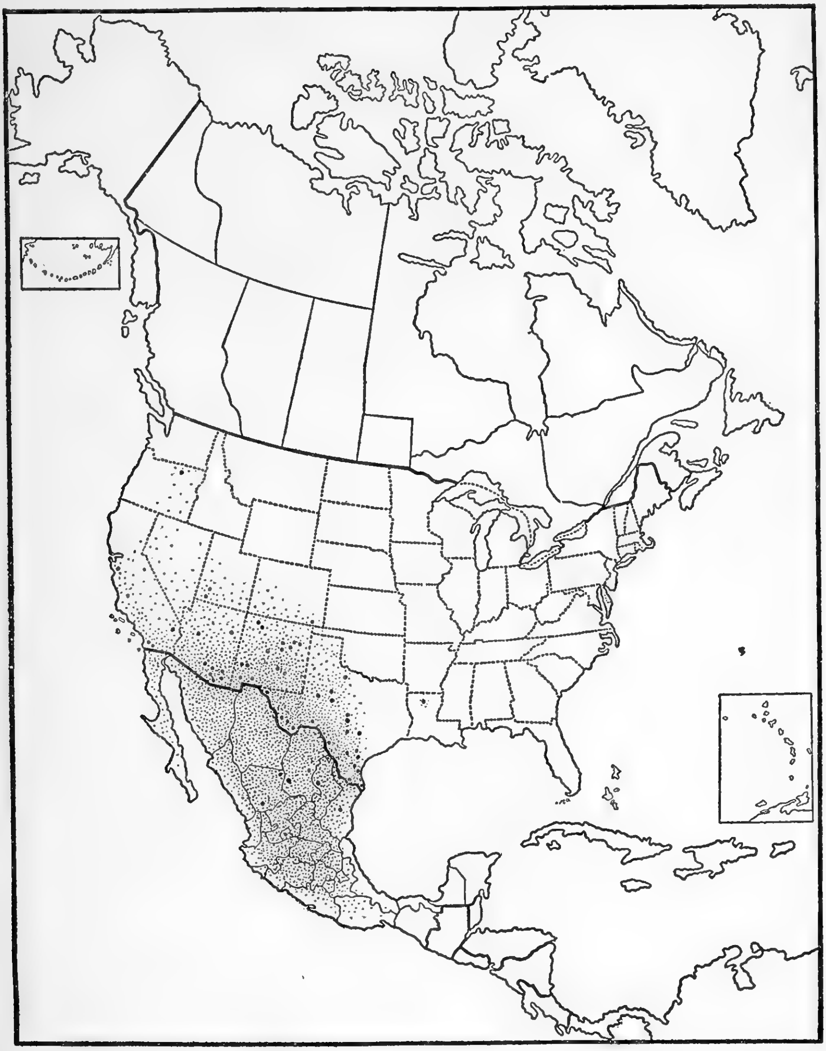


FIG. 2.—The spinose ear tick, *Ornithodoros megnini:* Distribution. The large dots show localities where the species has been collected in our investigation. The small dots show the probable range of the species. (Original.)

the Marx collection contains three lots with 15 well developed and 4 partially developed nymphs, which were taken from cattle in the Santa Lucia Mountains of Brazil. The accompanying map (fig. 2) shows approximately the normal range of the species in North America.

Although not recorded from Cuba, the species has probably been introduced there with cattle from the mainland, as large shipments of cattle from the infested districts are frequently made.

LIFE HISTORY.

Observations on the life history and habits of this species have been reported by Townsend (1893), by Hunter and Hooker (1907), and by Hooker (1908).

The egg.—With this species oviposition does not commence until mating has taken place. Large numbers of females have been isolated as nymphs in pill boxes and kept under observation for long periods after molting but in no case were eggs deposited in the absence of males. Where females after molting were at once placed in pill boxes with males, oviposition commenced in a comparatively short time. Of 13 females thus isolated, 3 commenced oviposition on the eighth day after molting; all had commenced on or before the twelfth day, with one exception, in which case eggs were first laid on the fifteenth day. The largest number of eggs deposited by any one of these 13 ticks was 1,546, the minimum number was 358, and the average 814. The eggs last deposited by any of the 13 ticks were laid 191 days after the ticks molted.

Oviposition in this species is remarkable on account of its intermittent nature. One tick ceased deposition for a period of 83 days, then deposited a considerable number of eggs. This phenomenon is evidently not dependent upon climatic conditions.

The minimum incubation period observed in the laboratory was 10 days; 412° F. of effective temperature appear to be required for embryonic development.

TABLE XI.—*Incubation period and larval longevity of Ornithodoros megnini.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Temperature during incubation. Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	*Days.*		°*F.*	°*F.*	°*F.*	°*F.*
Mar. 15	Apr. 4	21		88.0	46.0	68.03	526.17
27	Apr. 16	21		85.0	49.0	68.72	540.00
May 12	May 26	15		87.0	65.0	76.07	496.00
13	...do....	14		87.0	65.0	76.07	463.00
15	May 27	13		87.0	67.0	76.98	441.75
17	May 28	12		87.0	68.0	77.33	412.00
26	June 6	12	Before July 9	88.5	70.0	80.04	444.50
29	June 8	11	....do	90.0	70.0	81.30	421.25
June 4	June 15	12	July 10	91.5	69.0	80.19	446.25
8	June 20	13	Before July 9	91.5	69.0	80.29	484.75
18	June 29	12	July 11	90.0	73.0	81.63	461.50
29	July 10	12	July 27	93.0	70.5	81.00	456.00
July 26	Aug. 4	10		95.0	78.0	85.75	427.50
31	Aug. 9	10		99.0	73.0	86.25	432.50

THE SPINOSE EAR TICK, ORNITHODOROS MEGNINI.

Fig. 1.—Unengorged larva. Fig. 2.—Slightly engorged nymph, dorsal view. Fig. 3.—Slightly engorged nymph, ventral view. Fig. 4.—Engorged nymph, dorsal view. Fig. 5.—Engorged nymph, ventral view. Fig. 6.—Engorged female, dorsal view. Fig. 7.—Male, dorsal view. Fig. 8.—Female from which all eggs have been deposited, ventral view. Fig. 9.—Male, ventral view. (Original.)

The larva (Tables XI, XII, XIII).—The seed ticks of this species soon succumb if exposed to moisture such as is required by the ixodid ticks when kept in tubes on sand. When kept in dry pill boxes after hatching some have died in a few days while others have lived nearly a month. On April 22, 1910, about 2,000 eggs deposited between April 8 and April 22 were placed in a tube out of doors. On May 19 most of the eggs had hatched. On July 27 only 5 or 6 larvæ remained alive, and the last tick died August 3. Thus it appears that a period of 103 days may elapse from the deposition of the eggs to the death of the last larva. The larvæ usually remain in a dense bunch when not disturbed, but if aroused they become very active. Upon gaining access to the ear they attach to the sides of the concha.

As is shown in Table XII larvæ may molt as soon as the seventh day. In the five infestations recorded all had molted by the twelfth day after application to the ear. The appearance of the engorged larva has led several authors to speak of it as a pupa-like stage. It is not a resting stage, as the engorged larvæ move about when detached from the host. However, there may be a brief period of quiescence immediately prior to molting as occurs in the case of most ticks.

The nymph (Tables XII, XIII).—The nymphs engorge very slowly and require a comparatively long time for development. In feeding they usually produce scabs, which peal off in layers beneath and about the tick, thus requiring occasional reattachment. There appears to be a great variation in the period that the nymphs remain upon the host. In our observations the first nymph to leave was found in the bag attached to the ear on the thirty-first day after attachment as a seed tick or about three weeks after the larval molt. Others have remained attached to the host for nearly 7 months (209 days) and would undoubtedly have remained longer had it not been that the host was unwittingly sprayed with naphtholeum by an assistant. Our observations indicate that nymphs when well engorged may at times be dislodged by violent exercise on the part of the host.

In order to determine whether the cotton bags tied to the ears influenced the ticks in leaving the host, the bags were removed at intervals, when the exact number of ticks attached in the ears could be determined. Apparently they were not thus influenced in any way. It seems quite probable that normally the nymphs leave the host at night while the latter is at a resting place, in the corral or stable. The fact that they crawl up several feet from the ground and secrete themselves in cracks and crevices of the boards and timbers near the mangers, in the bark of trees, etc., was first observed by Mitchell, as reported by Hunter and Hooker (1907). Hooker has noticed

this same habit in observations made at an infested dairy in the vicinity of Corpus Christi, Tex. The cracks and crevices in front of the mangers were examined and numerous adults (both alive and dead), eggs, and larvæ were found. The greatest number were secreted several feet above the mangers. By crawling up in this way they find the dry quarters that appear to be required for development. Such a habit is of advantage to the larvæ in finding their way to the ears of the host, as cattle using infested stalls or rubbing against infested trees and fences undoubtedly pick up large numbers.

Our records show that nymphs may molt as soon as the sixth day after dropping. The spines characteristic of the nymphal stage are shed with the molted skin and are not found upon adults.

The adult (Tables XII, XIII).—In the adult stage this tick never engorges blood, a habit, so far as known, unlike that of any other species of tick. During the long periods of feeding as a nymph, development appears to take place sufficiently so that oviposition commences directly following fertilization, which may be as soon as 8 days after molting, or possibly sooner. The females may live for long periods if they do not find mates; thus a female collected July 22, 1905, and kept isolated in a small pill box (molting 6 days later) lived until January 22, 1907, a period of approximately 18 months. During this period no eggs were deposited. The longevity of 13 females varied from 66 to 260 days with an average longevity of 138.5 days. Males were placed with these as soon as the females became adult (molted). The longevity of these males varied from 77 to 166 days with an average of 100 days. These males and females were the largest individuals selected from a considerable number of collected nymphs. The greatest adult longevity observed in our investigation exceeded 638 days.

As in other argasid ticks, the sexes may be readily distinguished by the shape of the genital opening; in the female it appears as a transverse slit, while in the male it takes the form of a crescent.

Mating.—The species has frequently been observed in copulation in pill boxes. We have never observed the proboscis of the male inserted in the vulva as occurs in *Argas miniatus*, although this probably occurs. Christophers, who has studied ticks in India, states (1906, p. 9) that with *Ornithodoros savignyi* when placed in glass or porcelain vessels, a rapid tapping sound is sometimes heard which appears to be due to a vibration of the hinder portion of the body. We have frequently heard a tattoo-like sound made by adults of *O. megnini* kept in pill boxes and have considered it a sexual call. Upon removing the cover from the boxes the sounds have stopped and we have never observed a tick during the process. It appears that this habit is characteristic of the genus.

TABLE XII.—*The parasitic period of development of Ornithodoros megnini on a bovine.*

INFESTATION No. 1.

1907. Aug. 31, 2 p. m. Larvæ placed in ears.
1907. Sept. 8, 9 a. m. (8th day). Several molted.
1907. Sept. 9, 9 a. m. (9th day). All molted.
1907. Oct. 4 (34th day). One nymph dropped, molted to a male 11 days later (Oct. 15).
1907. Oct. 15 (45th day). One nymph dropped, molted to a male 13 days later (Oct. 28).
1907. Nov. 5 (65th day). One nymph dropped.
1907. Nov. 8 (68th day). One nymph dropped (8 by 5 by 3 mm.), molted to a male 31 days later (Dec. 9).
1907. Nov. 18 (78th day). One nymph dropped (7 by 4 by 2.5 mm.), molted to a male 13 days later (Dec. 1).
1908. Mar. 13 (195th day). One nymph dropped.
1908. Mar. 27 (209th day). The remaining nymphs (3) dropped. These were probably affected by spraying of the host Mar. 26.

INFESTATION No. 2.

1907. Oct. 13, 11 a. m. Larvæ placed in ear.
1907. Oct. 21, 9 a. m. (8th day). One molted.
1907. Oct. 23 (10th day). All but two or three molted.
1907. Oct. 25 (12th day). All molted.
1907. Nov. 4 (22d day). One nymph was removed, molted (Nov. 28) 24 days later.
1907. Dec. 3 (51st day). One nymph dropped.
1907. Dec. 4 (52d day). Two nymphs dropped.
1907. Dec. 5 (53d day). Two nymphs dropped.
1907. Dec. 23 (70th day). One nymph dropped.
1907. Dec. 24 (71st day). One nymph dropped.
1908. Jan. 14 (93d day). The last nymph dropped (dead).

INFESTATION No. 3.

1908. Apr. 7, 9 a. m. Larvæ placed in ear.
1908. Apr. 14, 4 p. m. (7th day). Two molted.
1908. Apr. 15 (8th day). All molted.
1908. Apr. 24. Three removed.
1908. May 8 (31st day). One nymph dropped (7 by 4 by 2 mm.).
1908. May 13 (36th day). One nymph dropped (7.5 by 5 by 3 mm.).
1908. May 17 (40th day). One nymph dropped (7 by 4.5 by 3 mm.).
1908. June 17 (71st day). Four nymphs dropped.
1908. June 22–29 (76th–83d day). Two nymphs dropped.
1908. Aug. 7 (121st day). Two nymphs dropped (7 by 4.5 by 2.5 mm; 8 by 5 by 3 mm.).
1908. Aug. 11 (124th day). One nymph removed (7 by 4.5 by 2.5 mm.).
1908. Sept. 8 (154th day). One nymph dropped (7 by 4.5 by 3 mm.).
1908. Sept. 24 (170th day). One nymph dropped.
1908. Oct. 2 (178th day). One nymph dropped during process of spraying host.

INFESTATION No. 4.

1908. July 2. Larvæ placed in ear.
1908. July 12 (10th day). Several molted.
1908. July 14 (12th day). All molted.
1908. Aug. 26 (24th day). Cotton-seed oil poured into ear, but none dropped.
1908. Aug. 31 (29th day). One dead (in bag), 5 attached.
1908. Sept. 10 (39th day). Chloronaphtholeum (1 to 75) poured into ear but none dropped.
1908. Sept. 24 (53d day). One nymph dropped.
1908. Oct. 10 (67th day). One nymph dropped.
1908. Oct. 12 (69th day). Three nymphs still present.

INFESTATION No. 5.

1909. June 10. Larvæ placed in ears.
1909. July 18 (8th day). Two molted.
1909. July 19 (9th day). Two molted.
1909. Aug. 6 (57th day). First nymph dropped.
1909. Oct. 1 (113th day). Last two nymphs dropped.

TABLE XIII.—*Summary of parasitic periods of Ornithodoros megnini.*

Infestation.	Larvæ.						Nymphs.				Total parasitic period.
	Attached.	First molted.		Last molted.		Parasitic period.	First dropped.		Last dropped.		
		Date.	Period following attachment.	Date.	Period following attachment.		Date.	Period following attachment.	Date.	Period following molting.	
	1907.	1907.	*Days.*	1907.	*Days.*	*Days.*	1907.	*Days.*	1908.	*Days.*	*Days.*
1	Aug. 31	Sept. 8	8	Sept. 9	9	8-9	Oct. 4	34	Mar. 27	201	209
2	Oct. 13	Oct. 21	8	Oct. 25	12	8-12	Dec. 3	51	Jan. 14	85	93
	1908.	1908.		1908.			1908.				
3	Apr. 7	Apr. 14	7	Apr. 15	8	7-8	May 8	31	Oct. 2	171	178
4	July 2	July 12	10	July 14	12	10-12	Sept. 24	53	Oct. 12[1]	59	69
	1909.	1909.		1909.			1909.		1909.		
5	June 10	July 18	8	July 19	9	8-9	Aug. 6	57	Oct. 1	105	113

[1] 3 attached.

LIFE CYCLE.

The larvæ may live under favorable conditions for 80 days. Upon gaining access to the ear they attach on the inside in the fold of the concha and even in the meatus, engorge, and molt in from 7 to 12 days. The nymphs engorge more slowly and digest blood as they develop. They may leave the host as soon as 31 days after molting or may remain for 201 days and probably longer. Upon leaving the host they usually crawl up several feet from the ground and secrete themselves in dry cracks and crevices. Here they molt, are fertilized, and deposit eggs. The incubation period in summer has been as short as 10 days. An effective temperature of at least 412° F. appears to be required for embryonic development. Unlike other ticks, this species never engorges blood in the adult stage.

The larvæ and more especially the nymphs are to be found on the host at all seasons of the year, although their seasonal abundance varies somewhat with local climatic conditions.

ECONOMIC IMPORTANCE.

This tick is undoubtedly of much more importance economically than is generally supposed. It is the source of great irritation to the host as evidenced by frequent and repeated shaking of the head. Townsend (1893) states that horses when badly infested have been known to roll as well. It is particularly injurious to calves which, unless treated and the ticks removed from their ears, frequently die as a result of the irritation. In some cases they run about shaking and rubbing the ears until exhausted. The milk yield of dairy cattle is undoubtedly lessened and in beef cattle the gain in weight correspondingly affected. On the range in the worst infested districts the loss of many head of cattle is chargeable to this tick. The deaths occur mainly during the winter and early spring, particularly

when feed is short and the cattle are poor. The ranchmen state that a heavily infested animal can often be told by the rough appearance of the hair.

There are numerous instances of this tick infesting the ears of man. Simpson (1901) reports a case in which two nymphs were taken, one from each ear of a gentleman in England who had camped in Arizona two months previous. The minute larvæ readily gain access to the external meatus of the human ear, where they develop to nymphs before causing much irritation. Intense pain may be caused by its presence, but usually there are no serious consequences.

NATURAL CONTROL.

We have observed that occasionally nymphs, which enter the meatus, are killed by being coated by the wax secreted in the ears of cattle. No natural enemies have been observed. Considerable moisture appears to be injurious to the nymphs and adults.

ARTIFICIAL CONTROL.

Dairy cattle and calves in infested districts should be frequently examined, the ticks removed, and some mild oil introduced into the ear. Townsend (1893), reporting upon this tick as observed in New Mexico, states that "a mixture of 20 parts of sweet oil to one of laudanum is sometimes poured into the ear as a remedy, but is of doubtful efficiency." Train oil, sometimes called British oil, he says, is highly recommended and he believes that it, as well as fish oil, will prove effective, but warns against the use of kerosene oil, which in the pure state has been known to cause temporary deafness. Townsend states that Dr. W. B. Lyon, of Las Cruces, N. Mex., recommended a little chloroform or carbolic acid in sweet oil or the dusting of calomel into the ears of affected horses.

In order to determine the value of cottonseed oil as a remedy, on August 26, 1908, some of it was poured into the ear of a bullock upon nymphs which had developed from larvæ applied on June 2. The results were negative. On September 10 chloronaphtholeum (1 to 75) was poured into the ears of the same animal without causing any of the ticks to drop.

DEVELOPMENT OF THE IXODIDÆ.

The second of the two families, the Ixodidæ or typical ticks, is represented in this country by 8 genera, including 36 described species and 3 varieties.

As based upon their molting habits, the ixodids may be divided into three groups: (1) The one-host ticks, or those that pass both molts upon the host; (2) the two-host ticks, or those which pass the first molt on the host but drop for the second, and (3) the three-host ticks, or those which drop for both molts.

The life cycles of 15 species and 2 varieties, representing the genera Margaropus, Rhipicephalus, Dermacentor, Hæmaphysalis, Ixodes, and Amblyomma, have been followed and are here considered. All molt twice and all but three drop from the host for both molts. *Dermacentor nitens*, *Margaropus annulatus*, and *M. annulatus australis* pass both upon the host. One other species, *Dermacentor albipictus*, has also been found by us to pass both molts upon the host. Molting closely follows engorgement in species which do not leave the host, while with those which drop, a quiescent period of 6 days or more follows. Some species burrow into the soil to the depth of an inch or more to pass the quiescent period and are thus afforded protection and drying out is largely prevented.

As with the Argasidæ the oviposition, incubation, and molting periods vary with the temperature, while the periods of engorgement upon warm-blooded hosts are but slightly influenced. The female usually dies within a few days after oviposition is completed. The color of engorged ticks varies considerably, particularly in the immature stages; the color may be nearly white, pink, slate-gray, or black, dependent upon the comparative amounts of blood, lymph, and inflammatory exudate imbibed.

Table XIV shows the maximum and minimum periods of engorgement, molting, and preoviposition in the species studied by us. Owing to the fact that the figures for some of the species are based upon a small number of observations made at one time of the year, they are hardly comparable with others which are chosen from a larger number of records made under various temperature conditions.

TABLE XIV.—*Maximum and minimum periods of engorgement, molting, preoviposition, and incubation of the ixodid ticks treated herein.*

Species.	Larvæ.		Nymphs.		Females.		Incubation period of eggs.
	Engorgement period.	Molting period.	Engorgement period.	Molting period.	Engorgement period.	Preoviposition period.	
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Amblyomma americanum	3-9	8-26	3-8	13-46	9-24	5-13	23-117
Amblyomma cajennense	3-27	10-73	3-13	12-105	7-12	9-20	37-154
Amblyomma dissimile	4-16	7-16	5-14	12-32	28	6	27-40
Amblyomma maculatum	3-7	7-121	5-11	17-71	14-18	3-9	21-10
Amblyomma tuberculatum	....	86-165	8-11	29-207	20-25	8-10	91-112
Dermacentor nitens	(1)	8-16	(1)	17-29	[2] 9-23	3-15	24-394
Dermacentor occidentalis	2-7	6-12	3-9	13-22	7-10	4-17	21-38
Dermacentor parumapertus marginatus	4-14	8-39	4-25	21-123	9-26	5-6	20-24
Dermacentor variabilis	4-7	7-11	4-8	6-25	8-16	5-14	24-43
Dermacentor venustus	2-8	6-19	3-9	11-170	8-17	5-17	16-36
Hæmaphysalis chordeilis	5-12	14-92	5-8	26-186	19	....	....
Hæmaphysalis leporis-palustris	4-10	18-134	4-8	13-124	17-35	3-15	22-40
Ixodes kingi	4-16	27-163	5-66	29-34	....	19-65	26-53
Ixodes scapularis	3-9	23-31	3-8	25-26	7+-30+	15-16	72
Margaropus annulatus	(1)	5-16	(1)	6-20	[2] 5-19	1-66	19-202
Margaropus annulatus australis	(1)	6-9	(1)	8-13	[2] 7-13	1-7	24-34
Rhipicephalus sanguineus	3-6	6-29	4-9	12-29	6-50	3-83	19-142

[1] This species molts on the host; hence the engorgement and molting periods can not be definitely separated, and are combined in the molting column.

[2] These periods include the number of days from the molting of the first nymph to the dropping of the first engorged female, and from the molting of the last nymph to the dropping of the last female.

LONGEVITY.

The period of life of the free ticks while awaiting a host is of particular importance economically. In general the larvæ of the species which pass their molts upon the host appear to be shorter lived than those of other ixodid ticks. *Dermacentor albipictus,* which molts upon the host, is an exception, however, as the larvæ of this species exhibit great longevity. Moisture is one of the most important factors in determining the longevity of ticks. After larvæ become weakened by fasting, a damp period has been observed to furnish conditions favorable to the development of various fungi upon them and to result in the destruction of large numbers. However, a certain amount of moisture is essential. The absence of moisture, especially during hot weather, is even more destructive than an excessive amount. The free nymphs are usually longer lived than the larvæ; in a number of species they have been found to live as long as the adults. According to Dixon (1910, p. 26) Lounsbury has found adults of *Rhipicephalus evertsi* to be alive, when kept in bottles, after a period of 18 months. Table XV summarizes our data on the longevity of the species observed. These records can not be considered as falling exactly into either of the two seasonal divisions used, as some were made during the spring and fall and others include part of summer and part of winter.

TABLE XV.—*Maximum longevity recorded for species of Ixodidæ.*

Species.	Larva.		Nymph.		Adult.	
	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Amblyomma americanum	[1] 150	[2] 297	476	476	393–430	393–430
Amblyomma cajennense	[2] 386	[2] 386	408	408	466	466
Amblyomma dissimile	[1] 95	....	130	....	129	103
Amblyomma maculatum	[2] 107	[2] 179	....	....	388–411	388–411
Amblyomma tuberculatum	....	[1] 95–110	81+	....	90	....
Dermacentor nitens	[1] 89–117	....	....	....	....	....
Dermacentor occidentalis	[2] 105–124	[2] 81	69	76–108	243+	243+
Dermacentor parumapertus marginatus	[1] 227	[1] 227	....	175	115–158	....
Dermacentor variabilis	[2] 335	[2] 335	200–216	200–216	202	233
Dermacentor venustus	[2] 92	....	185	252–271	413+	413+
Hæmaphysalis chordeilis	[2] 39+	....	....	74+	305	305
Hæmaphysalis leporis-palustris	[2] 258	[2] 217	342	342	588	588
Ixodes kingi	[2] 209	[2] 215+	....	68–171	104	....
Ixodes scapularis	....	75+	60+	....	....	....
Margaropus annulatus	[2] 125	[2] 279	....	....	....	....
Margaropus annulatus australis	[2] 82		....	....	....	....
Rhipicephalus sanguineus	[2] 80	[2] 131–138	75	183	158	214

[1] Record based upon larvæ hatched from eggs deposited on 1 or 2 days. Longevity computed from beginning of hatching to death of last larva.

[2] Record based upon larvæ hatched from all eggs deposited by a female. Longevity computed from beginning of hatching to death of last larva.

PARASITIC PERIOD.

There are a number of factors that influence, more or less, the parasitic periods of the ixodid ticks. Among these are the point of attachment to the host, fertilization, inability to detach, body temperature of the host, and, especially on cold-blooded hosts, the atmospheric tem-

perature. Engorgement may take place somewhat sooner when the tick is attached at a place where the epidermis is thin and the hypostome reaches an abundant supply of capillaries than where the epidermis is thicker and a poorer blood supply is found. Usually ticks attach in favorable locations on the host's body. However, we have found *Amblyomma tuberculatum* to attach to the edge of the carapace of the tortoise where the blood supply is exceedingly poor and probably insufficient ever to produce engorgement. Few observations have been made on the variation in the time required for engorgement upon cold-blooded animals from that on warm-blooded hosts. The few records that we here present, however, are sufficient to show that much longer periods are required upon cold-blooded hosts even at summer temperatures. On such hosts the parasitic periods will undoubtedly be found to vary with the temperature to which they are exposed and, as the temperature falls, the difference between the parasitic period on warm-blooded and cold-blooded animals will probably be found to increase.

Upon warm-blooded hosts, fertilization appears to be an important factor influencing the engorgement of females. While they usually engorge quite rapidly after being fertilized, we have observed unfertilized females to dry up and die while awaiting a mate; others, apparently unfertilized, have been observed to engorge, though not to repletion, and usually much slower than fertile ones. However, in some cases at least, engorgement has been observed to proceed equally as rapidly in unfertilized as in fertilized ticks. Definite conclusions can not be drawn in regard to this point until further observations are made. Some ticks do not engorge to repletion owing to the formation of scabs at the points of attachment, which are sloughed off along with the tick. Frequently, being unable to detach from the scab and unable to obtain blood, the tick dies attached to the host. We have frequently observed specimens which were very weak when applied to a host to die shortly after attachment. The species of ticks with short hypostomes often leave the host as soon as it is killed, but this is not the case with those having long hypostomes. Lounsbury (1899) has the following to say in regard to this habit:

> Ticks of various kinds have been credited by different people with leaving an animal the moment death takes place. My observation does not confirm this statement. Mr. Roberts shot a badly infested cow while I was at Cottesbrook, and I was particular to watch the behavior of the ticks. None but a few fully-engorged blues [*Margaropus decoloratus*] fell off at first. The pelt was removed and spread out on the grass. There were several dozen male tortoise shells [*Amblyomma hebræum*] and plenty of blues and reds [*Rhipicephalus evertsi*] and a few striped legs [*Hyalomma ægyptium*] present. Many of the males of all four kinds and a small proportion of the females detached themselves and wandered about the skin on the second and third days, but the majority of all kinds remained attached up to the fourth day, when because of the unbearable stench I discontinued my observations. Later it was observed that vast numbers of the ticks had dried out without disengaging themselves.

PREOVIPOSITION.

Following engorgement the female drops from the host, crawls to some protective covering, as into sand, cracks in the soil, beneath vegetation, litter, boards, or into cracks and crevices in buildings. In summer oviposition may commence as soon as the day following dropping, but usually the preoviposition period is of somewhat greater duration. In cold weather it may be delayed for as long as several months.

THE EGG.

The deposition of eggs continues in summer from one to two or more weeks, while during the colder months it may continue from one to several months. With the ixodid ticks oviposition occurs but once, during which time from one to many thousand eggs may be laid; with the completion of oviposition the female dies. The shortest incubation periods observed in the several species studied vary from 16 to 91 days. The longest incubation period recorded was 202 days. Temperature is the principal influencing factor, although humidity has some effect, particularly on the percentage of eggs hatching.

The manner of oviposition by Ixodes was first described correctly by Gené (1845), and later by Bertkau (1881). Curtice (1892, p. 242) first described the process in *Margaropus annulatus*, Lewis (1892) in *Amblyomma coronatum*, and Wheler (1906) in *Ixodes ricinus*. A detailed account of the process in *M. annulatus* has been given by Cushman as reported by Hunter and Hooker (1907, p. 16). Lewis's report of observations and that of Wheler are accompanied by illustrations and Cushman has made a drawing which we here present (see p. 127, fig. 9) of the organ protruded by *Amblyomma tuberculatum*. During oviposition the capitulum is retracted and a viscid vesicle to which Gené gave the name *vesica biloba* is protruded from between the capitulum and the scutum, from the lateral extremities of which two elevations are thrown out to be lengthened by evagination into two horns, lobes, or papillæ, as they have been described, which receive the eggs from the protruded oviduct. The glands of this vesicle secrete a viscid substance with which the lobes coat the eggs, thus causing them to adhere in a mass, and furnishing protection from drying. Gené found that eggs laid after destroying this sac, thus preventing the eggs from being covered, dried up and would not hatch, while others, newly laid by the same female and coated, hatched. Our observations appear to confirm those of Gené. In the case of the specimen of *A. tuberculatum* here figured, this sac was accidentally injured, resulting in the deposition of eggs which soon became dark and shrunken.

THE LARVA.

Upon hatching, the larvæ of many species remain clustered together for several days near the eggshells. Finally they crawl upon nearby herbage, such as grass, weeds, and even small trees, posts, or buildings, and there await the passing of a host. Some ticks, such as the species commonly found on dogs and rabbits, drop near the kennels or sleeping places of the hosts, and when the larvæ are ready to attach they may crawl about in search of the host.

Having once found a host the larvæ cling with great tenacity, crawling about over the body until a suitable place for attachment is found. The position of attachment upon the host varies with the species. Attachment may take place at once, or the tick may wander about for several days before attaching. This delay in attachment, the quantity and quality of the ingesta obtained by different specimens, and individual vitality account, in part at least, for the variation of from 2 to 14 days in the period between the application to hosts and the dropping of engorged larvæ from warm-blooded hosts and of from 10 to 18 days in the case of cold-blooded animals. After dropping, engorged larvæ usually remain active for only a few days before becoming quiescent, during which time they crawl to some protective covering. In some species, however, a considerable period is passed before the engorged larvæ become quiescent. From 10 days to several weeks may be required for the metamorphosis of the larva. This quiescent period varies primarily with the species, the temperature, and the humidity, the first two being the more important.

THE NYMPH.

In general the longevity of the nymphs is somewhat greater than that of the larvæ. In awaiting the hosts, their habits are very similar to those of the larvæ. In those species which molt upon the host, the adults crawl from the nymphal exuvia and reattach nearby. The periods of engorgement are quite similar to those of the larvæ, but the quiescent periods are somewhat longer.

There is considerable variation in the size of the engorged nymphs. The smaller ones usually become males and the larger become females. In the species with color markings on the scutum, as in the species of Amblyomma, the markings can be seen through the skin that is about to be shed. The sex can thus be determined from one to several days before the molt takes place. Following engorgement, if passed upon the host, molting takes place after a very short quiescent period. With the species which drop for the nymphal molt, from 1 day to as much as 6 months of activity are passed prior to the quiescent period. During this period of activity the nymphs attempt to find some protected place in which to transform. Par-

tially engorged nymphs usually have a much longer period of activity than fully engorged individuals. Low temperatures also lengthen this period. From 3 days to many months, varying somewhat with individuals, but particularly with the temperature, pass after the engorged nymphs drop before they transform to adults.

THE ADULT.

Upon molting, the adults may crawl upon herbage or other nearby objects and await a passing host. Some species, which commonly drop in places frequented by their hosts, may crawl about in search of them, as is the case with *Rhipicephalus sanguineus*. The longevity periods are usually somewhat greater than those of the nymphs. In the case of those species which molt on the host, the female, after issuing from the exuvium, reattaches nearby, while the male detaches and goes in search of a mate. Copulation usually takes place upon the host, but with several species of Ixodes it occurs off the host as well. There are also several records of species of other genera where copulation occurred when the ticks were not on a host, but we are inclined to the opinion that, aside from ticks of the genus Ixodes, mating very rarely occurs off the host. The periods required by adults for engorgement are usually longer than those of the immature stages, as fertilization must, as a rule, first take place. We have found this period to vary considerably even in the same species. Fertilization appears to be one of the principal factors involved; the quantity and quality of the ingesta and the vitality of the individuals are also important factors. The rate of engorgement is greatly increased after the female has become about one-half engorged. Occasionally fully engorged females are unable to detach and remain attached for several days after becoming fully engorged. Our records show that females have engorged and dropped as soon as 5 days after attachment, while others have remained upon the host as long as 50 days.

It has been found that females in the course of oviposition may first produce fertile eggs and later eggs which are dark, shrunken, and apparently infertile. Specimens of many of the species when not over one-third engorged may be detached and if uninjured will reattach. There is a great difference in the number of eggs deposited by the various species, varying with the size of the tick and also with the size of the eggs. This variation in the maximum number of eggs deposited ranges from 2,240 per tick in *Hæmaphysalis leporis-palustris* to as many as 11,265 by our native species, *Amblyomma maculatum*, and 20,000 by 2 African species (*A. hebræum* and *A. variegatum*). The males often remain upon the hosts for long periods after the females have dropped; thus the females usually do not have to wait long for a mate after finding a host. The habit of the male of remaining upon

the host for a considerable time accounts for the fact that the males of the larger species, such as *A. maculatum* and *A. tuberculatum*, are more commonly collected than the females. It has been noted that with the species in which the male is small and inconspicuous the females have been more frequently collected.

Genus IXODES Latreille.

The genus Ixodes is represented by more species in the United States than any other genus. On account of this fact, the general distribution of the members of the group throughout the country, and the occurrence of the species on a large number of small mammals, no doubt a considerable number of undescribed forms will be found in the future.

The black-legged tick (*Ixodes scapularis*) and the California Ixodes (*Ixodes californicus*) are the species of most importance in this country. These species are both closely related to the European castor-bean tick (*Ixodes ricinus*), and are thought by Bishopp to be only varieties of the European form. This view is also held by Nuttall and Warburton.

None of the members of this genus has been connected with disease transmission in this country, but in Germany *Ixodes ricinus* has been shown by Kossel and his associates (1903) to be capable of transmitting bovine piroplasmosis, and Stockman (1908) has shown it to play the same rôle in England.

Ixodes ricinus, on account of its general distribution and importance in Europe, has received the attention of a number of investigators. This species has been studied in England by Wheler (1899) and in Germany by Kossel and his coworkers (1903). *Ixodes pilosus* has been studied by Lounsbury (1900–1906) and by Mally (1904). The life histories of only two species of the genus, namely, *Ixodes scapularis* and *Ixodes kingi*, are presented here, although several other species are now being studied. All of the species observed drop from the host to pass both molts.

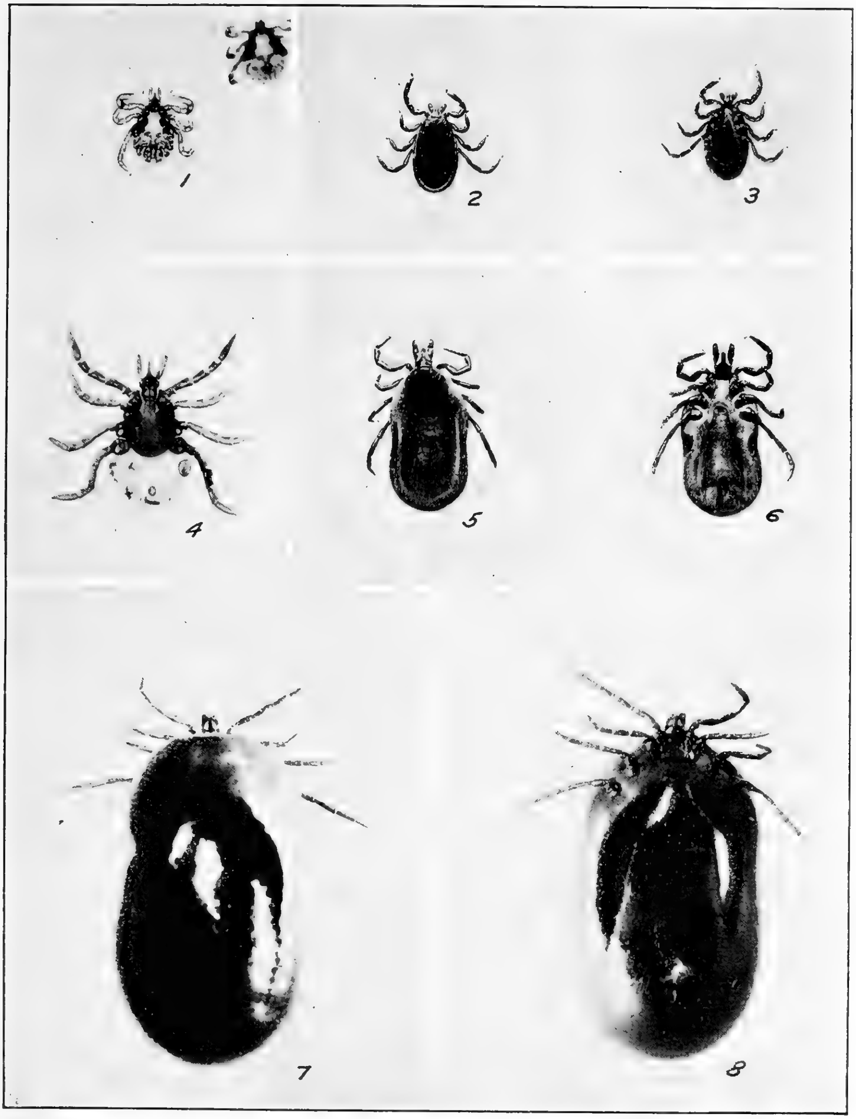
THE BLACK-LEGGED TICK.

Ixodes scapularis Say.

DESCRIPTIVE.[1]

Adult (Pl. V, figs. 2, 3, 5–8).—Males about 2.3 by 1.25 mm. Females, unengorged, from 2.5 by 1.25 mm. to 3 by 1.5 mm.; engorged, about 10 by 7 by 5.5 mm. The females are usually dark brown, and the males almost black; scutum and legs in both sexes black, or nearly so. Partially engorged females that are nearly white, and others that are of a dark red color, are frequently found upon the host.

[1] The capitulum has been included in all the measurements of the length of this and other species recorded in this bulletin.



THE BLACK-LEGGED TICK, IXODES SCAPULARIS.

Fig. 1.—Unengorged larva. Fig. 2.—Male, dorsal view. Fig. 3.—Male, ventral view. Fig. 4.—Unengorged nymph. Fig. 5.—Partly engorged female, dorsal view. Fig. 6.—Partly engorged female, ventral view. Fig. 7.—Fully engorged female, dorsal view. Fig. 8.—Fully engorged female, ventral view. (Original.)

Nymph (Pl. V, fig. 4).—Unengorged, 1.5 by 0.75 mm.; engorged, from 2.3 by 1.5 by 1.25 mm. to 2.7 by 1.5 by 1.25 mm. Color, unengorged, dark smoky brown, shield and capitulum nearly black, legs lighter; engorged, dark bluish gray. Capitulum 0.317 mm. long (from tip of palpi to postero-lateral angles of basis capituli); scutum 0.586 mm. long by 0.491 mm. wide.

Larva (Pl. V, fig. 1).—Unengorged, from 0.616 by 0.371 mm. to 0.746 by 0.474 mm.; engorged, 1.28 by 0.76 mm. to 1.4 by 0.9 mm. Color, unengorged, smoky brown; scutum, capitulum, and legs somewhat darker than body; engorged, slate-gray to black. Capitulum 0.222 mm. long (from tip of palpi to base of emargination of shield); scutum 0.297 mm. long by 0.304 mm. wide.

Egg.—Size, about 0.445 by 0.386 mm.; light brown, shining, smooth.

HOST RELATIONSHIP.

No type host was given by Say when he described this species. In certain sections of the South it occurs in considerable numbers on the dog and on cattle. The species has also been recorded from the deer, sheep, horse, and, in the immature stages, from birds, including the quail, blue jay, and thrush. One of the writers has found this tick to be common on the dog at Hawthorn, Fla. Mr. W. W. Yothers collected a number of adults on dogs at Orlando, Fla. Both sexes were collected from an opossum at Hawthorn, Fla., and at Tanglewood, Tex., Mr. C. T. Atkinson took a partially engorged female on that host.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 3.)

No type locality was given for this species by Say, who described it. It appears to have been collected from Maryland south to Florida, and in the Central States from Indiana, Iowa, and Missouri, as well as in Louisiana and Texas. A male specimen recorded from Pennsylvania by Neumann may prove to be this species. Some 12 female specimens collected from *Felis pardalis* in Costa Rica and determined by Neumann as *Ixodes affinis* have been identified by Mr. Nathan Banks as *I. scapularis*. Mr. E. A. Schwarz took a male and female when he was beating hanging vines in heavy timber, a short distance west of Tampico, Mex.

LIFE HISTORY.

But little has previously been published on the biology of this species.

The egg.—Two engorged females which were collected at Hawthorn, Fla., on December 21, 1907, and sent to the laboratory, commenced depositing, one on January 5, the other on January 6; 15 and

16 days, respectively, after collection. The eggs deposited were not counted, but it was estimated that at least 3,000 had been deposited by one of the ticks. A well-engorged female collected on a cow at Dallas, Tex., November 24, 1908, began depositing on December 11, thus having a preoviposition period of 17 days.

FIG. 3.—The black-legged tick, *Ixodes scapularis:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the tick. (Original.)

In the laboratory at a mean temperature of 61° F., eggs deposited January 6 commenced hatching on March 17, an incubation period of 72 days. An accumulated effective temperature of 1,318° F. was required for their incubation.

The larva (Tables XVI, XVII).—Larvæ which hatched in March have lived for 2½ months in the laboratory and then attached to a bovine and engorged. Their longevity is undoubtedly considerably longer than this period.

Larvæ were found to engorge and leave the host as soon as 3 days after application, the longest period required being 9 days.

TABLE XVI.—*Engorgement of larvæ of Ixodes scapularis.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.									Total number dropped.
		1	2	3	4	5	6	7	8	9	
May 6, 1908	Bovine	0	0	18	12	5	0	0	0	0	35
May 23, 1908	...do	0	0	0	1	0	7	22	3	1	34
May 6, 1909	...do	0	0	2	1	0	0	0	0	0	3
May 11, 1909	...do	0	0	1	0	0	0	0	0	0	1

In May at a mean temperature of 77.19° F. engorged larvæ have commenced to molt on the twenty-third day, the last to molt shedding its skin on the thirty-first day. Thus an accumulated effective temperature of 786° F. was required.

TABLE XVII.—*Molting of larvæ of Ixodes scapularis.*

Date engorged larvæ dropped.	Host.	Number.	Larvæ molted—days following dropping.									Total number molted.	Temperature from dropping to date first tick molted.		
			23	24	25	26	27	28	29	30	31		Maximum.	Minimum.	Average daily mean.
													°F.	°F.	°F.
May 9, 1908	Bovine	18	0	0	4	3	5	1	0	1	0	14	88.50	63.00	77.21
May 10, 1908	...do	20+	2	3	5	1	1	0	8	0	0	20	87.50	65.00	77.19
May 11, 1908	...do	5	0	3	2	0	0	0	0	0	0	5	88.50	65.00	77.62
May 29, 1908	...do	4	0	1	0	Others dead.				0	0	1	91.50	69.00	80.72
May 30, 1908	...do	3	2	0	0	0	0	0	0	0	1	3	91.50	69.00	80.86
May 31, 1908	...do	3	0	0	0	0	0	0	0	0	1	1	91.50	69.00	80.90
May 14, 1909	...do	2	1	0	0	0	0	0	0	0	0	1	97.00	47.00	86.64
Total		55	...	...	...	...	...	...	...	...	...	45			

The nymph (Tables XVIII, XIX).—A number of nymphs which molted in June lived 2 months in the laboratory and then attached to a host. Nymphs engorged and dropped as soon as the third day after application, the last to drop leaving the host on the eighth day.

TABLE XVIII.—*Engorgement of nymphs of Ixodes scapularis.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.								Total number dropped.
		1	2	3	4	5	6	7	8	
June 20, 1908	Bovine	0	0	1	0	3	1	4	2	11
July 10, 1908	...do	0	0	0	0	1	1	0	0	2
July 11, 1908	...do	0	0	0	0	2	0	0	0	2

A nymph molted in June in 25 days, when the mean temperature was 82° F. A total effective temperature of at least 955° F. was required. Thus an exceptionally high effective temperature appears to be required for the nymphal molt. There is also a considerable variation in the periods in which the nymphal molt takes place. The length of the molting period of nymphs which become males is practically the same as that for nymphs which transform to females.

TABLE XIX.—*Molting of nymphs of Ixodes scapularis.*

[♂ = Male. ♀ = Female.]

Date engorged nymphs dropped.	Host.	Number.	Nymphs molted—days following dropping.										Number molted.			Temperature from dropping to date first tick molted.		
			25	30	34	36	38	42	43	50	52	56	Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
																°F.	°F.	°F.
June 23, 1908	Bovine..	1				1♀							0	1	1	95.0	70.5	82.74
June 25, 1908	...do.....	3				1♀				1♀		1♂	1	2	3	95.0	70.5	82.95
June 26, 1908	...do.....	1	1♀										0	1	1	94.0	70.5	82.20
June 27, 1908	...do.....	4		1♂	1♀			1♂			1♂		3	1	4	95.0	70.5	82.75
June 28, 1908	...do.....	2					1♀						0	1	1	95.0	70.5	83.45
July 15, 1908	...do.....	1							1♀				0	1	1	99.0	73.0	85.28
July 16, 1908	...do.....	2				1♂			1♀				1	1	2	99.0	73.0	85.76
Total...	....	14											5	8	13			

The adult.—The longevity of unfed males and females has not been determined owing to the limited supply of adults at hand. When removed from a host the adults do not live long unless kept quite moist; even the engorged females die unless they are kept under such conditions.

Males and females which would not attach when placed on a host September 1 attached readily when given an opportunity 4 days later. The following day they were found mated. On the morning of the second day the males had detached, but in the afternoon they were again paired. One male remained with a female for 4 days, while others changed to a second mate during this time. Our observations indicate that ordinarily mating is not continuous upon the host. It appears that mating may also take place off the host. We have observed an engorged, unattached female and an unattached male in coitu shortly after they were taken from the hair of a hunting dog. In the course of this act the mouthparts of the male are introduced into the genital pore of the female.

A partially engorged female, collected in Florida, engorged and dropped on the seventh day after attachment to a bovine at the laboratory. A female applied to a bovine September 1 attached 4 days later and remained attached until September 25, when it was rubbed off by the host. At that time it was about one-third engorged, measuring 4 by 2.2 by 1.4 mm. A second female attached at the

same time was sloughed off on October 1, being but slightly engorged at that time. The reason these two females did not engorge more rapidly is not known. It was not due to a lack of fertilization, as mating took place while the ticks were on the host. A slightly engorged female that was applied to a bovine host on December 26, 1907, dropped 8 days later fully engorged, measuring 10 by 7 by 5.5 mm.

LIFE CYCLE.

Oviposition may commence in 15 days after dropping. Three thousand or more eggs are deposited by the engorged tick. In winter at a mean temperature of 61° F. incubation may take place in 72 days, a total effective temperature of 1,318° F. being required. Larvæ may engorge in 3 days and at a mean temperature of 77° F. commence to molt 23 days later, an accumulated effective temperature of 786° F. being required. Nymphs may engorge in 3 days after being applied to a host. In summer 25 or more days appear to be required for the nymphal molt. A total effective temperature of at least 1,017° F. appears necessary for this transformation. A slightly engorged female collected on a dog reattached and engorged upon a new host in 7 days.

ECONOMIC IMPORTANCE.

The black-legged tick is not known to be of any great economic importance. In Germany and England a closely related species, *Ixodes ricinus*, transmits bovine piroplasmosis and it is possible that this species may do so. While this tick has been found by Prof. H. A. Morgan to be rather numerous on cattle in northern Louisiana, it appears to be of minor importance as a cattle pest. In extensive collections made in Texas agents of this bureau have failed to find it in sufficient numbers to attract attention as a pest. In the vicinity of Hawthorn, Fla., however, it is the source of considerable annoyance to hunting dogs, and it has recently been found to be a pest of considerable importance to cattle and sheep in northern Tennessee.

NATURAL CONTROL.

Observations relating to natural enemies of this species are lacking.

ARTIFICIAL CONTROL.

Where hand picking is not sufficient to keep the species in control, mopping with one of the coal-tar products should be practiced.

THE ROTUND TICK.

Ixodes kingi Bishopp.

The common name of this species is applied on account of the globular form of the engorged female.

DESCRIPTIVE.

Adult (Pl. VI, figs. 4–9).—Males 2.85 by 1.51 mm. to 3.15 by 1.88 mm. Females, unengorged, 2.6 by 1.6 by 0.7 mm. to 2.7 by 1.7 by 0.7 mm.; engorged, 11.6 by 10.4 by 7 mm. to 13 by 12.8 by 8.5 mm.; unengorged males and females light yellowish brown; scutum somewhat darker; engorged females appear almost globular; shield and mouthparts inconspicuous; abdomen light blue-gray in color. The grooves on the dorsum and venter practically disappear on engorged specimens.

Nymph (Pl. VI, figs. 2, 3).—Unengorged, about 1.25 by 0.8 mm.; length of capitulum 0.37 mm. (from tip of palpi to base of emargination of scutum); scutum 0.66 mm. long by 0.68 mm. wide; body ovoid, yellowish brown, somewhat translucent; engorged, about 2.3 by 1.3 by 0.8 mm.; slate color, legs and shield light colored as before engorging.

Larva (Pl. VI, fig. 1).—Unengorged, 0.657 by 0.413 mm.; length of capitulum 0.19 mm. (from tip of palpi to base of emargination of scutum); scutum 0.277 mm. long by 0.335 mm. wide; body ovoid, very light yellow, translucent; engorged, 1.19 by 0.727 mm.; bluish gray in color.

Egg.—Ellipsoidal, light yellow, translucent. The maximum size of ten eggs was 0.541 by 0.420 mm.; the minimum size 0.528 by 0.392 mm. and the average size 0.534 by 0.401 mm.

HOST RELATIONSHIP.

The type host of this species is the badger. Our knowledge of the hosts of the immature stages of this tick is limited owing to the difficulty met with in rearing immature stages of Ixodes to adults, and to the fact that the specific identity of the larvæ and nymphs of Ixodes can not be reliably determined. Immature stages of what are very probably this species have been collected upon the following hosts: Badger, larvæ and nymphs; pocket gopher (*Thomomys clusius ocius*), larvæ; marmot (*Marmota flaviventer*), larvæ and nymphs; skunk, nymphs; dog, nymphs; pine squirrel (*Sciurus hudsonicus richardsoni*), larvæ and nymphs; pika (*Ochotona princeps*), larvæ and nymphs; chipmunk (Eutamias), larvæ and nymphs; ground squirrel (*Citellus columbianus*), larvæ and nymphs. Many of the above lots were collected by Mr. W. V. King in western Montana. The sexes were taken together on badger in three

instances and on dog in two cases. Twenty lots have been collected in which females only were found. The hosts and number of lots on each is as follows: Dog, 8; pocket gopher, 2; prairie dog, 1; mink, 1; wolf, 1; spermophile, 1; marmot, 1; skunk, 1; kangaroo rat (*Perodipus richardsoni*), 1; unknown, 3. From the large number of ticks of both sexes found on the badger it would appear that that animal is one of the more important natural hosts of the species. We have been able to engorge the larvæ experimentally on the guinea pig, rabbit, and ox, and nymphs have been engorged on the guinea pig and ox.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 4.)

The type locality of this species is Meeteetse, Wyo. The species appears to be widely distributed over the Western States from Texas to Montana. We have specimens which were collected in Texas, New Mexico, California, Utah, Wyoming, Idaho, and Montana. The tick appears to be most abundant in the northern part of its range. It is quite probable that this species occurs in Canada and possibly in Mexico, although no collections have been made in those regions.

LIFE HISTORY.

No studies have been made heretofore upon the biology of this tick.

The egg (Table XX).—Since specimens of this tick have not been engorged at the laboratory, only those sent in from various localities having been used in our studies, it is not possible to determine definitely the relation between the length of the preoviposition period and temperature.

During June and July, 1909, a preoviposition period of 19 days was recorded. This is the shortest preoviposition period which we have observed. The longest preoviposition period occurred during June, July, and August, 1909, and was 65 days. Four other specimens had preoviposition periods of 27, 28, 29, and 30 days, respectively. Deposition continued from 10 to 36 days. The shortness of the first period seemed to be due to the fact that the female was not fully engorged. The maximum number of eggs deposited by an individual was 4,706, and the average number 3,179. The females live but a short time after deposition is complete.

One female collected on June 23, 1909, began to deposit on the sixty-fifth day after collection. During the first 2 days of oviposition 454 eggs were deposited. On subsequent days deposition continued as follows: 104, 168, 169, 166, 107, 233, 59 (during 2 days), 43, 44, 9, a total of 1,556 eggs being deposited during 13 days. A female collected June 29, 1909, began to deposit on the twenty-sixth day after collection. On that date and subsequent days deposition proceeded as follows: 485, 226, 169, 231, 246, 156, 312 (during 2 days),

104, 105, 109, 103, 113, 234, 97, 100, 115, 84, 94, 66, 69, 48, 10, a total of 3,276 eggs being deposited during the period of 133 days. A third individual, for which the date of collection was not recorded, deposited as follows: From June 9 to 11, 72 eggs. On subsequent

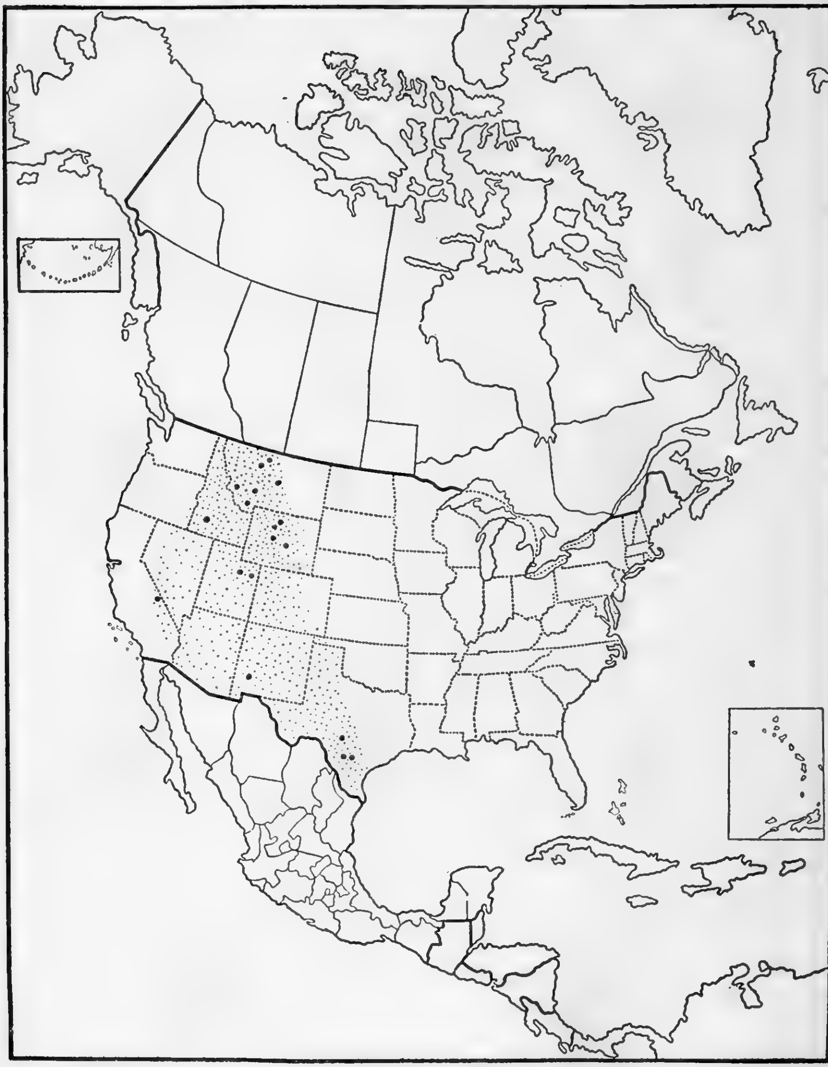
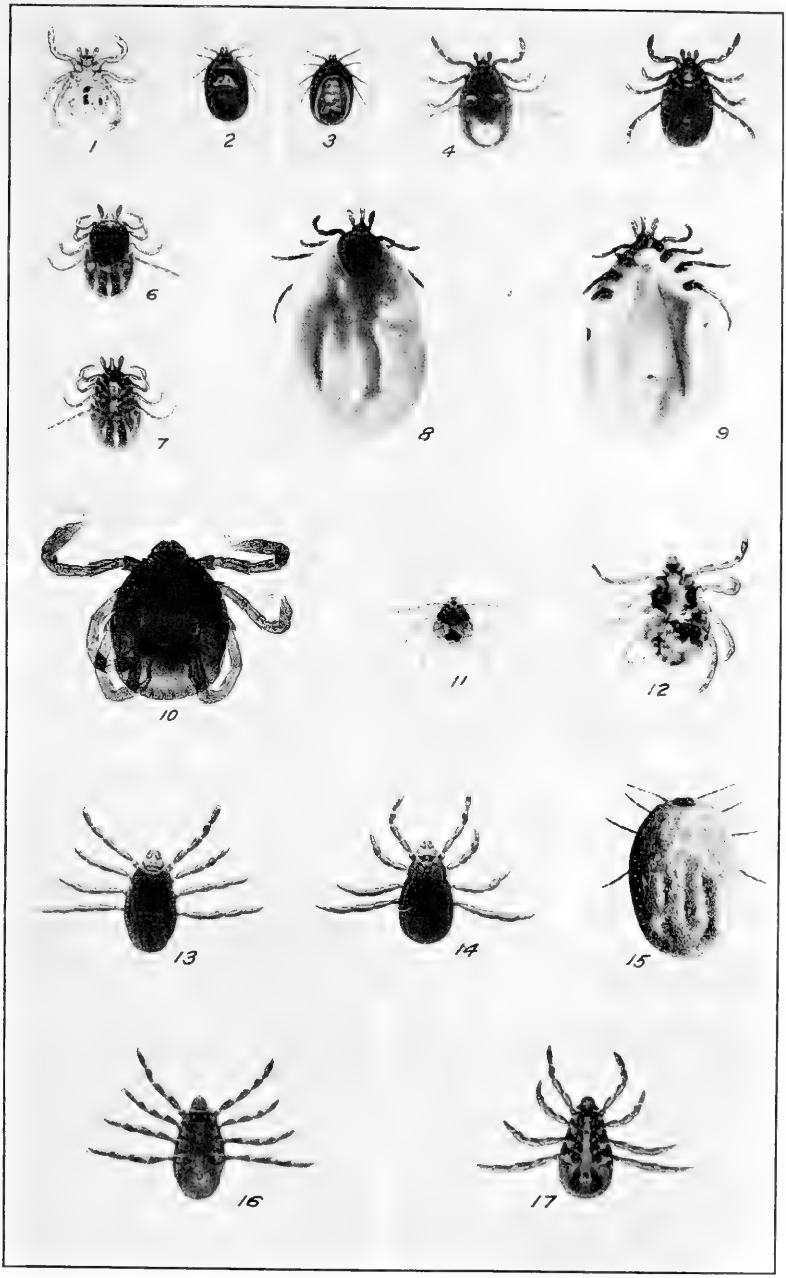


FIG. 4.—The rotund tick, *Ixodes kingi:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots show the probable distribution of the species. (Original.)

days, 319, 261, 372, 282, 306, 169, 181, 166, 130, 121, 105, 112, 148, 173, 142, 160, 152, 183, 102, 123, 121, 108, 118, 195, 80, 85, 115, 92, 13 (during 2 days), a total of 4,706 eggs being deposited during the period of 34 days. Many of the eggs deposited by the individual last



THE ROTUND TICK, IXODES KINGI, AND THE BROWN DOG TICK, RHIPICEPHALUS SANGUINEUS.

Ixodes kingi: Fig. 1.—Unengorged larva. Fig. 2.—Engorged nymph, dorsal view. Fig. 3.—Engorged nymph, ventral view. Fig. 4.—Male, dorsal view. Fig. 5.—Male, ventral view. Fig. 6.—Unengorged female, dorsal view. Fig. 7.—Unengorged female, ventral view. Fig. 8.—Partially engorged female, dorsal view. Fig. 9.—Partially engorged female, ventral view. *Rhipicephalus sanguineus:* Fig. 10.—Unengorged larva. Fig. 11.—Unengorged larva. Fig. 12.—Unengorged nymph. Fig. 13.—Unengorged female, dorsal view. Fig. 14.—Male, dorsal view. Fig. 15.—Partially "deposited-out" female, dorsal view. Fig. 16.—Unengorged female, ventral view. Fig. 17.—Male, ventral view. (Original.)

recorded were shriveled and brownish and failed to hatch. Another fully engorged female, collected on a dog, March 29, 1910, began depositing on April 28, and deposited 130 eggs during the next 5 days. A few days later this female began to turn dark and soon died. The eggs deposited failed to hatch, thus suggesting that the tick may not have been fertilized.

The minimum incubation period observed was 26 days. This record was made in the laboratory during September, 1909, when the mean temperature was 85.67° F. A maximum incubation period of 53 days occurred during August, September, and October with a mean daily temperature of 84.58° F. The total effective temperature required for embryonic development appears to be at least 1,109° F.

TABLE XX.—*Preoviposition, incubation, and larval longevity of Ixodes kingi.*

Engorged female collected.	Deposition began.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
						Max.	Min.	Average daily mean.	Total effective.
1909.	1909.	1909.	*Days.*		*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
June 29	July 25	Sept. 1	39	Feb. 25–Mar. 30, 1910.	177–210	110	77	89.32	1,806.5
Do	July 29	...do	35			110	77	89.25	1,618.8
Do	Aug. 13	Oct. 4	53	About May 1, 1910	About 178.	110	66	84.58	2,203.7
Do	Aug. 10	Sept. 28	50			110	56	84.74	2,387
Do	Aug. 15	Sept. 29	46			110	56	85.34	1,947.6
Do	Aug. 18	Sept. 24	38	Apr. 27–July 19, 1910	215–298	110	61	86.65	1,658.7
Do	Sept. 1	Sept. 26	26			101	61	85.67	1,109.4
1910.	1910.	1910.							
Mar. 29	Apr. 27	June 17	52	Before Sept. 25, 1910.	100	100	62.75	75.36	1,682.7
Apr. 7	May 16	June 24	40			100	60	80.61	1,504.4
May 7	June 1	July 14	44	Feb. 8, 1911	209	100	66	84.51	1,826.4
June 18	July 5	Aug. 5	32	Feb. 4, 1911	183	104	73	88.09	1,442.9

The larva (Tables XX–XXI).—The larvæ of this tick have been found to live at least 215 days. The lot upon which this record was based hatched September 24, 1909. Fifty were still alive April 27, 1910. Other lots hatched in midsummer were found to live nearly as long as the one cited. Larvæ may drop engorged as soon as the fourth day after application to a host, while some may remain on the host 16 days and even then not become fully engorged. Although no engorgements were obtained from two or three lots of larvæ applied to bovines and guinea pigs, most of the lots tested attached readily and a large percentage of them engorged. Attachment was found to take place usually within an hour after the time of application to a host. Many specimens were found detached from the host when they were from one-fifth to two-thirds engorged. This premature dropping is probably due to the ease with which they are displaced by the host animal after they have become partially engorged.

TABLE XXI.—*Engorgement of larvæ of Ixodes kingi.*

Date larvæ applied.	Host.	Number.	Larvæ dropped engorged—days following application.										Total number dropped.	State of engorgement.
			4	5	6	7	8	9	13	14	15	16		
Sept. 15, 1909	Guinea pig.	120	0	11	51	25	8	5	....	....	....	....	100	One-half to fully.
Oct. 1, 1909	Rabbit.....	13	1	1	1	....	....	....	....	....	....	....	3	....
Oct. 28, 1909	Bovine.....	100	4	7	15	5	6	....	....	....	....	....	37	One-half to fully.
Nov. 4, 1909	.....do......	100	27	31	6	2	....	....	....	....	....	....	66	....
Nov. 16, 1909	.....do......	100	0	[1]	25	5	2	....	....	....	....	....	32	....
Jan. 14, 1910	Guinea pig.	110	0	0	0	6	0	0	2	....	....	....	8	One-half to two-thirds.
Sept. 28, 1910	.....do......	40	0	0	0	0	0	0	0	11	0	2	13	One-fifth to fully.
	Total.	583	....	....	....	....	....	....	....	....	....	....	259	

[1] The larvæ which dropped on this date were included with those which dropped on the following day.

The larval molting period varies greatly, as was shown in experiments in which 54 individuals were observed, and seems to be governed mainly by temperature conditions. The shortest molting period observed was 27 days; the longest, 163 days. The mean temperature during these two periods was 74.43 °F. and 59.65° F., respectively. A total effective temperature of 821.1° F. appears to be required for this transformation. The large percentage of mortality during molting in some of the lots was probably due in part to the fact that a considerable number of individuals was not fully engorged when detached from the host. During summer, when the molting period is shorter, the mortality would probably be smaller, as the effect of drying out would not be so great. Undoubtedly humidity is an important factor, at this stage of their development.

The nymph (Tables XXII–XXIII).—Of 20 nymphs which molted to larvæ between January 29 and April 2, 1910, 16 were put on hosts during March and April. The last individual of the four remaining died between June 9 and July 19, 1910. Thus the longevity of these 4 individuals was between 68 and 171 days. Another lot of 8 nymphs, which molted from larvæ between March 22 and April 4, 1910, died between June 9 and July 19, 1910, thus living for a period of 66 to 119 days. The minimum nymphal engorgement period recorded was 5 days. In one instance a nymph remained on the host 66 days, at the end of which time it was accidentally detached when only two-thirds engorged. Attachment was usually found to take place soon after application, but occasionally nymphs remained in proximity to a host for 36 hours before attaching. The readiness with which attachment takes place and the rate of engorgement appear to depend to some extent upon the vitality of the individuals when applied. If nymphs are weak when applied to a host they are usually slow in attaching, and frequently many die on the host

before becoming engorged to any extent. Guinea pigs and bovines were the only hosts upon which nymphs were placed for engorgement in our experiments.

TABLE XXII.—*Engorgement of nymphs of Ixodes kingi.*

Date nymphs applied.	Host.	Number.	Number attached.	Nymphs dropped—days following application.					Total number dropped.	State of engorgement.
				5	7	15	16	66		
Oct. 25, 1909	Bovine	1	1					1	1	Two-thirds.
Nov. 11, 1909	do	5	4			1	2		3	Fully.
Mar. 29, 1910	Guinea pig	8	4				1		1	Four-fifths.
Apr. 14, 1910	Bovine	1	1	1					1	Fully.
Apr. 19, 1910	do	8	4		1	1			2	Three-fourths to fully.
	Total	23							8	

Of a large number of nymphs applied to hosts only 3 were brought to the adult stage. The records on these were made during April, May, and June, 1910. The molting periods for these 3 individuals, all of which were females, were 29, 33, and 34 days, respectively. An average daily mean temperature of 73.29° F. was recorded during the minimum molting period and a total effective temperature of 878.4° F. was accumulated.

TABLE XXIII.—*Molting of engorged nymphs of Ixodes kingi.*

Date engorged nymphs applied.	Host.	Number.	Engorged nymphs molted—days following dropping.			Number molted.			Temperature from dropping to date first tick molted.		
			29	33	34	Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
									°*F.*	°*F.*	°*F.*
Apr. 19, 1910	Bovine	1			1♀	0	1	1	90.0	51.50	71.87
Apr. 26, 1910	do	1	1♀			0	1	1	90.0	58.50	73.29
May 4, 1910	do	1		1♀		0	1	1	100.0	59.00	76.34
	Total	3					3	3			

The adult.—One individual of a lot of 3 females which molted between May 23 and June 6, 1910, lived about 104 days. One partially engorged female lived 102 days after being removed from a host on September 20, 1909. This tick appeared to be killed by the cold. Owing to the fact that very little material was reared to the adult stage and both sexes were not obtained at the same time, no records of engorgement were obtained. One female put on a guinea pig attached in a few hours and died on the host during the second day after application. This tick appeared to take some blood prior to its death.

No observations have been made on mating. Very few males have been collected in nature as compared with the number of females taken. Making allowance for the fact that some collectors may have overlooked the males, it appears that females are much more abundant on hosts than are males.

The engorged females are usually well covered with a yellowish waxy substance, apparently secreted on all parts of the less chitinized integument. This substance frequently accumulates in considerable masses around the capitulum and genitalia. The engorged females are almost globular, and the legs are delicate and scarcely touch the surface upon which the female lies. Movement of the engorged females is therefore practically impossible.

LIFE CYCLE.

Larvæ may live for at least 215 days. They may engorge in 4 days and molt as soon as the ninth day after dropping. The longest molting period recorded was 163 days. A total effective temperature of at least 822° F. appears necessary for this molt. Nymphs may live for at least 66 days in summer and probably longer in winter. They may engorge as soon as the fifth day after application and molt as soon as the twenty-ninth day after dropping. A total effective temperature of 878.4° F. is required for the transformation to adult. The length of the engorgement period of females has not been determined. The shortest preoviposition period was 19 days and the longest 65 days. Deposition may continue for 34 days and as many as 4,706 eggs be deposited. Eggs may hatch as soon as 29 days after deposition and appear to require a total effective temperature of 1,109° F. for incubation.

All stages seem to be most numerous on hosts in midsummer, although we have specimens collected from March to November. Further investigation will probably show them to be present on hosts in greater or less numbers throughout the year.

ECONOMIC IMPORTANCE.

This tick has never been recorded as a parasite of man or of domestic animals other than the dog, and since it seldom occurs in great numbers on this host it appears to be of practically no economic importance.

NATURAL CONTROL.

No natural enemies of this species have been recorded. Eggs in a bunch of about 100 which were exposed to the sun on the ground for about 3 hours all shriveled and failed to hatch. During this period the highest atmospheric temperature was 110° F. and the highest soil surface temperature was 133° F.

Genus HÆMAPHYSALIS Koch.

Two species of the genus Hæmaphysalis occur in the United States both of which are quite widely distributed. One of the two (*Hæmaphysalis chordeilis*) is of economic importance on account of its habit of attacking turkeys. The life history and habits of 3 exotic species have been studied, namely, *H. leachi*, the active agent in South Africa in the transmission of canine piroplasmosis, by Lounsbury (1902, 1904, 1905), *H. proxima* in Brazil by Rohr (1909), and *H. punctata*, which has been found by Stockman (1908) to transmit bovine piroplasmosis. This latter species has recently been reported by Hadwen (1910) to occur in Manitoba. It must have been introduced from abroad, probably on cattle from England, where it is a very common pest. All three of these foreign species, as well as the two species (*H. leporis-palustris* and *H. chordeilis*) which have been studied by us drop from the host for both molts. One of the authors (Hooker 1909*a*, pp. 252–253) was led to believe that this species molts on the hosts on account of molted skins of larvæ being found on the heads of quail associated with larvæ and nymphs belonging to the genus Hæmaphysalis. We have since reared *H. chordeilis* and as we have had considerable numbers of both the larvæ and nymphs to drop from the hosts engorged and then molt, we must conclude that the skins found on the quail were shed by individuals of some other bird-infesting species.

THE RABBIT TICK.

Hæmaphysalis leporis-palustris Packard.

The rabbit tick (*Hæmaphysalis leporis-palustris* Packard) is so named from the fact that it is the most widely distributed and common tick which attacks the rabbit in the United States.

DESCRIPTIVE.

Adult (Pl. VII, figs. 4–6).—Males from 1.6 by 1 mm. to 2.25 by 1.25 mm. Females, unengorged, from 2.25 by 1.25 mm. to 2.5 by 1.5 mm.; engorged, from 6 by 3.5 by 2.5 mm. to 11.3 by 7.5 by 5.3 mm.; males and females very dark brown or black in color with no light markings; engorged females slate color.

Nymph (Pl. VII, figs. 2, 3).—Unengorged, about 1.33 by 0.8 mm., dark reddish brown; engorged, 2.5 by 1.75 mm., dark bluish gray to almost black; capitulum 0.218 mm. in length (from tip of palpi to postero-lateral angles of basis capituli); scutum 0.422 mm. long by 0.436 mm. wide.

Larva (Pl. VII, fig. 1).—Unengorged, about 0.534 by 0.385 mm.; dark smoky brown; scutum lighter in center; engorged, about 1.33 by 0.88 mm; ovoid, very dark brown to black, often with a pink tinge

for some time after dropping; capitulum 0.164 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.246 mm. long by 0.305 mm. wide.

Egg.—The average size for 10 eggs which were measured was 0.493 by 0.396 mm. Ellipsoidal, dark brown to black in color, shining, smooth.

HOST RELATIONSHIP.

The hares and rabbits are the principal hosts, especially of the adult stage. (*Lepus*) *Sylvilagus palustris* is the type host. We have collected the tick on about 7 species of rabbits, and have also taken the adults on robin, quail, meadowlark, and domestic cat. The immature stages have been taken in abundance on quail and meadowlark and in fewer numbers on chaparral cock and Brewer's blackbird. Immature stages of what are probably this species were taken on the thrush, field lark, jackdaw, blue jay, magpie, and pine squirrel. A single nymph was taken on a groove-billed ani at Victoria, Tamaulipas, Mex., and a larva, probably of this species, was taken on a small sparrow at Monterey, Mex. On rabbits the species is nearly always found attached to the ears, either inside or out. On birds the ticks are nearly always found upon the head, largely upon or about the crest. However, occasionally they attach on the neck and about the eyes and ears.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 5.)

The type locality for this species is North Carolina. The species occurs in many States, from Massachusetts to California and Mexico. The States from which the species is recorded are Alabama, Arizona, Arkansas, California, Colorado, Florida, Idaho, Illinois, Kansas, Louisiana, Massachusetts, Minnesota, Montana, New Mexico, New York, North Carolina, Nevada, Oklahoma, Oregon, Tennessee, Texas, Virginia, Washington, and Wyoming. It has also been taken in Mexico. In western Texas, New Mexico, and Arizona the species is not commonly found, the rabbit Dermacentor being the tick ordinarily met with on rabbits. We have taken it in large numbers from rabbits in Montana and neighboring States.

LIFE HISTORY.

Observations on the biology of this species have been reported by Hunter and Hooker (1907) and by Hooker (1908, 1909).

The egg (Tables XXIV, XXV).—In one instance oviposition began on the third day after dropping. The mean temperature during this period beginning June 15, 1909, was 89.5°F. The longest preoviposition period observed was 15 days. This record was made on a

well-engorged female collected March 7, 1910. The mean temperature for the period was 68.62° F. The average preoviposition period of 25 ticks observed during the spring and summer months was 8 days. The engorged female is usually comparatively small, due

FIG. 5.—The rabbit tick, *Hæmaphysalis leporis-palustris:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots show the probable distribution of the species. (Original.)

probably to the fact that it is confined to the smaller mammals and to bird hosts. Owing to its rather small size it deposits comparatively few eggs. Eight females were under observation. The largest number of eggs deposited by a single female was 2,240; the smallest

number was 59, and the average number was 1,517. This maximum record was made by a fully-engorged female collected on a rabbit May 7, 1909. This was the largest engorged female seen by us, measuring 11.3 by 7.5 by 5.3 mm. Deposition began on the seventh day after collection and continued for 20 days. The largest number of eggs deposited during one day was 303, which occurred on the first day of oviposition.

The preoviposition period of the eight females ranged between 4 and 9 days, with an average of 6.4 days. The period of oviposition varied from 5 to 20 days. The female having the shortest oviposition period probably died prematurely. Death of the females usually took place on the day following the completion of egg laying. In one case it occurred on the fifth day after deposition ceased.

Eggs kept out of doors were, in one instance, found to hatch in 22 days. The mean temperature during this period was 90° F. and the total effective temperature 1,034° F. In the laboratory the incubation period has been found to be as short as 23 days for eggs deposited in June. During this period the mean temperature was 82° F., an effective temperature of about 902° F. being required for hatching. The longest incubation period observed in about 25 lots of eggs deposited during the spring and summer was 40 days.

TABLE XXIV.—*Incubation and longevity of larvæ of Hæmaphysalis leporis-palustris.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation period.			
					Maximum.	Minimum.	Average daily mean.	Total effective.
		Days.		*Days.*	*°F.*	*°F.*	*°F.*	*°F.*
May 20-23, 1906	June 20	32	Mar. 5, 1907	258				
May 24-29, 1906	June 23	31	....do	255				
Sept. 2-5, 1906	Sept. 26	25	May 11, 1907	217				
Sept. 4, 1907	Sept. 27	24	Apr. 13, 1908 (several alive).	199+	102.0	50.0	78.72	821.5
Sept. 7-9, 1907	Sept. 30	24	Mar. 17, 1908 (one alive).	168+	102.0	50.0	77.3	788.5
June 29, 1908	July 21	23	Sept. 21, 1908	62	94.0	70.5	82.25	902.75
May 6, 1909	June 8	34	Jan. 22, 1910 (one alive).	228+	89.5	59.0	81.49	1,308.75
June 18, 1909 [1]	July 9	22	Sept. 18-28, 1908	71-80	102.0	81.0	90.0	1,034.00
Apr. 14, 1910	May 23	40	July 19 to Aug. 20, 1910.	57-89	90.0	51.5	70.91	1,116.50
May 7, 1910	June 9	34	....do	40-72	100.0	59.0	77.29	1,285.75
June —, 1910	July 14		Feb. 3, 1911	204				

[1] This lot was kept out of doors.

The larva (Tables XXIV, XXV).—The longevity of the larvæ has been found to be as great as 258 days under favorable conditions. The larvæ which survived for this period hatched on June 20 and thus passed through the summer months, which are the most unfavorable to long survival. Many lots of larvæ which hatched early in the summer of 1909 died in about two months. The excessive heat dur-

ing August of that year was at least partially responsible. Engorged larvæ have dropped from rabbits as soon as the fourth day following attachment, but on a bovine 6 days was the shortest period of engorgement. The greatest number drop from the fifth to the eighth day, 10 days being the longest time required for engorgement.

TABLE XXV.—*Engorgement of larvæ of Hæmaphysalis leporis-palustris.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
Sept. 30, 1907	Rabbit	0	0	0	0	25	27	33	7	5	1	98
Oct. 29, 1907	...do	0	0	0	5	77	71	29	5	1	4	192
Nov. 15, 1907	Bovine	0	0	0	0	19	75	27	11	2	0	134
Mar. 11, 1908	...do	0	0	0	0	0	13	19	4	0	0	36
Mar. 19, 1908	...do	0	0	0	0	11	131	115	24	0	0	281

The molting of engorged larvæ was observed in 384 cases. Larvæ which dropped in March at a mean temperature of 68.7° F. molted in 18 days, an effective temperature of 463° F. having been required. The longest period passed before molting was for 2 larvæ which dropped November 22, 1907, and molted 134 days later. The mean temperature during this period was 61.98° F. Unfortunately our records do not include individuals which engorged during the summer months.

The nymph (Tables XXVI, XXVII).—The greatest nymphal longevity observed was 342 days. This record was made on two nymphs which were collected on a rabbit on June 19, 1909, by Mr. W. V. King. One of a few nymphs which molted from larvæ April 19, 1908, lived for 307 days. A number of other lots of ticks, which were observed from the time they molted to nymphs, lived from 78 to 246 days. The longevity of a number of lots of collected individuals, which had become from slightly to one-half engorged, was from 34 to 334 days. The minimum engorgement period of nymphs which we have observed was 4 days, the last ticks dropping on the eighth day after application.

TABLE XXVI.—*Engorgement of nymphs of Hæmaphysalis leporis-palustris.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
Oct. 29, 1907	Rabbit	0	0	0	0	0	2	1	0	0	0	3
Feb. 25, 1908	Bovine	0	0	0	0	0	1	0	1	0	0	2
Apr. 4, 1908	...do	0	0	0	0	0	3	6	2	0	0	11
June 2, 1908	...do	0	0	0	5	24	14	2	0	0	0	45
May 22, 1909	Rabbit	0	0	0	1	0	0	0	0	0	0	1

Nymphs which dropped June 8, 1908, and were kept at a mean temperature of 80° F. commenced molting on the fourteenth day after dropping. A total effective temperature of 486° F. accumulated during this period. When the mean temperature was 58.34° F. molting began on the eighty-ninth day after dropping. The longest period from dropping to molting which we have observed was 124 days. The last three lots of ticks, the molting of which is recorded in the following table, were collected from wild hosts and were not all fully engorged. This may have tended to lengthen slightly the molting period of some of the individuals.

The nymphal molting period of the two sexes is practically the same. Our observations indicate that a very large percentage of the engorged nymphs reach the adult stage even when dropping takes place in the winter.

TABLE XXVII.—*Molting of engorged nymphs of Hæmaphysalis leporis-palustris.*

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.																			
			13	14	15	16	25	26	27	29	30	48	49	53	58	84	85	89	94	96	97	98
Nov. 4,07	Rabbit	1	0	0	0	0	0	0	0	0	0	0	1♂	0	0	0	0	0	0	0	0	0
Nov. 5,07	...do	1	0	0	0	0	0	0	0	0	0	1♀	0	0	0	0	0	0	0	0	0	0
Apr. 10,08	Bovine	3	0	0	0	0	0	0	1♀	2♂	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 11,08	...do	6	0	0	0	0	1♀	0	1♂	1♀	1♀	0	0	0	0	0	0	0	0	0	0	0
Apr. 12,08	...do	2	0	0	0	0	0	1♂, 1♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 6,08	...do	5	0	1♂	1♂, 1♀	2♂	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 7,08	...do	24	0	2♂, 5♀	4♂, 8♀	2♂, 2♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 8,08	...do	14	1♂, 1♀	3♂, 2♀	4♀	1♂	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 9,08	...do	2	0	0	1♂	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 10,08	Quail	2	0	0	0	0	0	0	0	0	0	0	0	1♀	1♀	0	0	0	0	0	0	0
Nov. 25,09	Rabbit	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	2	2
Dec. 29,09	Chaparral cock	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♂	1♂, 1♀	1♂	1♀	0	0
Total		93																				

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.					Number molted.			Temperature from dropping to date first tick molted.		
			100	104	112	113	124	♂	♀	Total.	Maximum.	Minimum.	Average daily mean.
											°F.	°F.	°F.
Nov. 4,07	Rabbit	1	0	0	0	0	0	1	0	1	....	....	....
Nov. 5,07	...do	1	0	0	0	0	0	0	1	1	....	....	....
Apr. 10,08	Bovine	3	0	0	0	0	0	2	1	3	83.0	47.0	68.84
Apr. 11,08	...do	6	0	0	0	0	0	1	3	4	83.0	47.0	68.98
Apr. 12,08	...do	2	0	0	0	0	0	1	1	2	83.0	47.0	70.07
June 6,08	...do	5	0	0	0	0	0	4	1	5	91.5	69.0	80.52
June 7,08	...do	24	0	0	0	0	0	8	15	23	91.5	69.0	80.57
June 8,08	...do	14	0	0	0	0	0	5	7	12	91.5	69.0	80.39
June 9,08	...do	2	0	0	0	0	0	1	......	2	91.5	69.0	80.55
Nov. 10,08	Quail	2	0	0	0	0	0	0	2	2	82.0	34.0	59.15
Nov. 25,09	Rabbit	27	2	1	2	1	2	......	......	24	83.0	17.0	58.34
Dec. 29,09	Chaparral cock	6	0	0	0	0	0	3	2	5	87.0	17.0	61.62
Total		93	....	....	....	....	....	26	33	84	....	....	....

♂=Male. ♀=Female.

The adult (Table XXVIII).—The longevity of adults of this species is probably equal to that of any other ixodid tick. In a tube which contained a lot of about 24 adults which molted from nymphs shortly before September 29, 1909, the last individual, a female, died May 10, 1911, having lived at least 588 days. A male in another lot which molted to adults between February 22 and March 29, 1910, lived for 403 days. In a third test a female in a lot which molted between March 23 and April 4, 1910, died on May 10, 1911, after a period of 401 days. One male in a lot of about 6 males and females which became adult April 15, 1908, lived for 395 days. The longevity of several other lots of ticks upon which the date of molting was recorded ranged between 109 and 355 days. These lots became adult in the spring and early summer months. A longevity of from 17 to 167 days was observed in the case of 10 lots of adults collected on hosts during 1909 and 1910.

Considerable difficulty has been met with in getting females to engorge. Although males and females have attached in conspicuous places on the ears of tame rabbits, we have failed to observe them in copulation. A small female dropped in 17 days, but the only female which attained full size required three weeks for engorgement.

The last individual, the engorgement of which is recorded in the following table, was placed on the host without males. Mr. George Wolcott, who observed this engorgement, found that it attached in less than half an hour. It remained for at least three weeks before any appreciable engorgement took place. In the last three days engorgement was very rapid.

TABLE XXVIII.—*Engorgement of females of Hæmaphysalis leporis-palustris.*

Adults applied.	Host.	Female dropped engorged.	Period of attachment.	Size engorged.
			Days.	
July 8, 1908	Rabbit	July 25	17	6 by 3.5 by 2.5 mm.
Do	..do	July 29	21	10 by 6 by 3 mm.
Do	..do	Aug. 3	26	Scratched off.
Jan. 14, 1911	..do	Feb. 18	35	Fully engorged.

LIFE CYCLE.

This tick may commence to oviposit as soon as the fourth day after leaving the host. The largest number of eggs deposited by an individual was 2,240. The eggs have been found to hatch in 22 days. A total effective temperature of at least 902° F. is required for incubation. Larvæ have been found to live 258 days. They may engorge and drop in 5 days after attaching to a host. Molting of larvæ may begin in 18 days. A total effective temperature of 463° F. appears to be required for the transformation to nymphs. Nymphs may live

for 342 days. They may engorge in 4 days after attachment and begin molting 13 days after dropping. A total effective temperature of about 486° F. is required to produce this transformation. Adults may live for 588 days without food. Both sexes have been found together in abundance on wild hosts, but copulation has not been observed in ticks reared experimentally. Females may drop engorged in 17 days after attachment to a host.

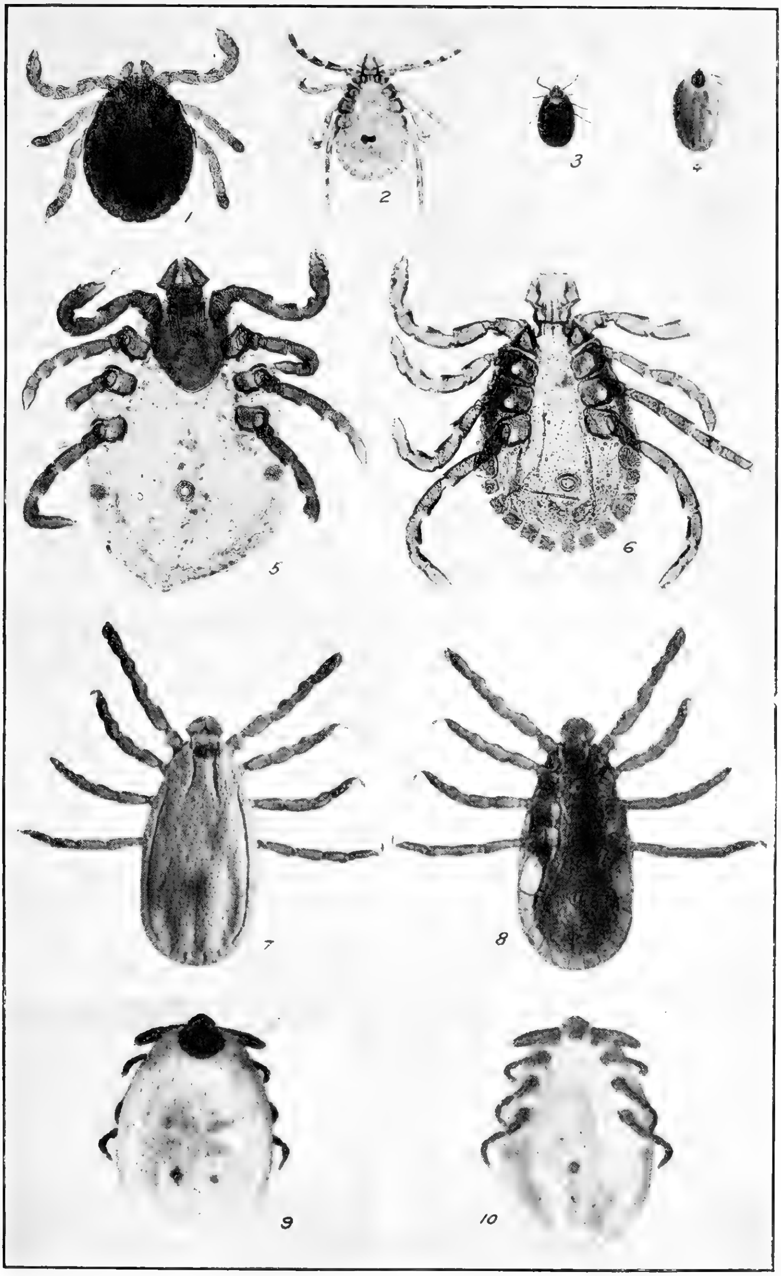
The three stages of the rabbit tick have been taken from hosts in nature during all seasons of the year. We have found the immature ticks in great numbers on ground-inhabiting species of birds in the fall and winter; they may, however, be equally numerous in the summer.

ECONOMIC IMPORTANCE.

On account of the fact that this tick confines its attack to rabbits and wild birds, it is of no importance economically. In a few instances the species has been known to become so abundant on wild rabbits as to render them so weak that they could be easily killed by their enemies. Mr. W. V. King killed two snowshoe rabbits (*Lepus bairdi*) at Florence, Mont., on April 3, 1910, which were infested with 1,033 ticks. Many of these were fully engorged females. The large number of specimens found on quail and meadowlarks leads us to believe that in some cases the young of these hosts may be killed by tick attack.

NATURAL CONTROL.

The bird hosts of the rabbit tick undoubtedly destroy a considerable number of them, although they also serve as disseminators of the species. As has been stated, rabbits have been observed by us to devour engorged ticks and no doubt some specimens are injured by the scratching of this host. The smaller birds, such as sparrows, and certain reptiles and batrachians, are also probably of some importance in the destruction of this tick. It is known that this species is parasitized in the nymphal stage by a chalcidid. This parasite (*Ixodiphagus texanus*), the first recorded as having been reared from a tick, was described by Dr. L. O. Howard (1908) from individuals reared at the tick laboratory from engorged nymphs collected by Mr. J. D. Mitchell in Jackson County, Tex. A single specimen in each of two different lots of engorged nymphs was found to be parasitized by this insect. One of these lots was collected March 10, 1907, on a cottontail rabbit and the other May 1, 1907, on a jack rabbit. Subsequent collections in that locality have failed to reveal other parasitized specimens.



THE RABBIT TICK, HÆMAPHYSALIS LEPORIS-PALUSTRIS, AND THE BIRD TICK, HÆMAPHYSALIS CHORDEILIS.

Hæmaphysalis leporis-palustris: Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph. Fig. 3.—Engorged nymph. Fig. 4.—Engorged female. Fig. 5.—Partially engorged female (balsam mount). Fig. 6.—Male (balsam mount). *Hæmaphysalis chordeilis:* Fig. 7.—Male, dorsal view. Fig. 8.—Male, ventral view. Fig. 9.—Engorged nymph, dorsal view. Fig. 10.—Engorged nymph, ventral view. (Original.)

THE BIRD TICK.

Hæmaphysalis chordeilis Packard.

The common name of this species is applied on account of the fact that birds are its principal hosts.

DESCRIPTIVE.

Adult (Pl. VII, figs. 7, 8).—Males from 2.8 by 1.5 mm. to 2.9 by 1.6 mm. Scutum light gray in color, shading into amber anteriorly; marginal strip bluish white; legs and capitulum amber. Females, unengorged, from 2.8 by 1.4 mm. to 2.9 by 1.8 mm.; engorged, about 9 by 6.6 by 4 mm.; reddish brown in color when unengorged, scutum without markings.

Nymph (Pl. VII, figs. 9, 10).—Unengorged, 1 by 0.65 to 1.4 by 0.72 mm.; light brown in color, scutum darker; engorged, about 2.43 by 1.79 mm.; color dark gray. Capitulum 0.217 mm. in length (from tip of palpi to base of emargination of scutum); scutum 0.446 mm. long by 0.447 mm. wide.

Larva.—Unengorged, from 0.552 by 0.402 to 0.574 by 0.430 mm.; body ovoid, yellowish brown; engorged, from 1.4 by 0.8 by 0.6 mm. to 1.5 by 1 by 0.6 mm.; abdomen slate color. In most cases three distinct longitudinal white lines are to be seen on the dorsum; shield very dark brown, almost black posteriorly, shading to a pale yellow-brown anteriorly. The legs and mouthparts are translucent yellowish brown. Capitulum 0.125 mm. in length (from tip of palpi to base of emargination of scutum), scutum 0.240 mm. long by 0.308 mm. wide.

Egg.—No eggs of this species have been seen by us.

HOST RELATIONSHIP.

The type host of this species is the nighthawk. The species has a comparatively wide range of bird hosts. Those species which are more or less ground-inhabiting seem to be more frequently infested. The immature stages of this tick are frequently found in large numbers, usually attached to the heads of the hosts. They are very frequently associated on the hosts with the immature stages of *Hæmaphysalis leporis-palustris.* The following birds have been found to act as hosts: meadowlark, jackdaw, red-winged blackbird, marsh hawk, quail, and domestic turkey. Mr. Banks mentions having seen a nymph, probably of this species, from the killdeer. The examinations of birds in Texas indicate that the meadowlark is by far the most commonly infested host. We also have a fairly reliable record of three adults of this species having been taken from a prairie chicken in Texas. As has been stated, the ticks are usually found to attach on the top of the head. They are also found around the eyes and ears and occasionally under the bill.

GEOGRAPHICAL DISTRIBUTION.

The type locality for this species is Milton, Mass. Specimens have also been taken at Norwich and Taftsville, Vt. Most of the other collections were made in Victoria and Refugio Counties in Texas by Mr. J. D. Mitchell. We have one authentic record from D'Hanis, Medina County, Tex., and one of the authors (Hooker) collected larvæ and nymphs which he thought were this species at Grand Cane, La., and Hawthorn and Quincy, Fla. It is very probable that this tick has a wide range of distribution, but owing to the fact that little collecting has been done upon birds in other localities, the range of the species is not fully known.

LIFE HISTORY.

Little has been published on the biology of this tick. Hooker (1909*a*) reports the finding of molted larval skins attached to the head of a meadowlark. These were associated with engorged larvæ of this genus and it was thought that they might be exuvia of the bird tick.

The egg.—Owing to the difficulty in securing engorged females no records have been made upon preoviposition and oviposition periods. The number of eggs deposited by this species has not been determined. Dr. Philip B. Hadley, of the Rhode Island Agricultural Experiment Station, kindly sent Mr. Nathan Banks a large number of larvæ which hatched about August 15 from eggs deposited by a number of engorged females collected on turkeys at Norwich, Vt., June 28, 1909. These larvæ were forwarded to us at Dallas, Tex., by Mr. Banks.

The larva (Tables XXIX–XXX).—The longevity of the larva of this species has not been definitely determined. Larvæ of one lot which hatched about August 15 lived at least 39 days. At the end of that period they were placed on hosts.

As is indicated in Table XXIX, larvæ have been engorged on rabbits and guinea pigs. Two attempts to engorge them on chickens failed, though a few were found to attach. Attachment was found to take place very soon after the larvæ were applied, usually within 5 to 30 minutes. Dropping began as soon as the fifth day after attachment. The longest period of engorgement observed was 12 days. The weighted average time from application to dropping in the case of the 33 larvæ engorged was 7.5 days.

TABLE XXIX.—*Engorgement of larvæ of Hæmaphysalis chordeilis.*

Date larvæ applied.	Host.	Number.	Larvæ dropped engorged—days following application.								Total number dropped.	State of engorgement.
			5	6	7	8	9	10	11	12		
1909.												
Sept. 7	Rabbit	85	6	9	2	2	0	2	0	0	21	Fully.
Sept. 7	Hen	28	0	0	0	0	0	0	0	0	0	
Sept. 17	Guinea pig	75	....	....	....	1	....	1	....	....	2	Fully.
Sept. 18	Hen	15	0	0	0	0	0	0	0	0	0	
Sept. 22	Rabbit	7	0	0	0	1	0	1	1	0	3	Two-thirds to fully.
Sept. 24	....do	15	0	0	0	2	3	1	0	1	7	Two-thirds to fully.
	Total	225	....	....	....	....	....	....	....	....	33	

At a mean temperature of 79.05° F. molting began on the fourteenth day after dropping. When the mean temperature fell to 53.98° F. 76 days elapsed before molting began. This and the other long molting period given in the table were recorded on larvæ collected from wild hosts, and although the state of engorgement of the ticks was not recorded, there is little doubt that they were not fully engorged. This would tend to lengthen the molting period as has been found true in all observations made by us on this point. A total effective temperature of 505° F. appears to be required for this transformation.

TABLE XXX.—*Molting of engorged larvæ of Hæmaphysalis chordeilis.*

Date engorged larvæ dropped.	Host.	Number of larvæ.	Engorged larvæ molted—Days following dropping.													Total number molted.	Temperature from dropping to date first tick molted.		
			14	15	16	17	18	19	21	26	32	42	67	76	92		Maximum.	Minimum.	Average daily mean.
1909.																	*°F.*	*°F.*	*°F.*
Sept. 12	Rabbit.	6	...	2	1	...	...	...	...	...	...	...	...	...	...	3	98.50	59	79.84
Sept. 13	...do	9	1	...	...	1	2	...	...	1	...	1	...	...	...	6	96.50	59	79.05
Sept. 14	...do	2	...	1	...	...	...	...	...	...	...	...	...	...	...	1	95.50	56	77.28
Sept. 17	...do	2	...	1	...	...	1	...	...	...	...	...	...	...	...	2	95.50	56	76.75
Sept. 25	...do	1	...	...	...	...	...	...	...	...	1	...	...	...	...	1	92.50	51	72.38
Sept. 30	...do	1	...	...	...	...	...	...	...	1	...	...	...	...	...	1	92.50	51	72.77
Oct. 2	...do	2	...	...	...	...	...	1	...	1	...	...	...	...	...	2	92.50	52.50	73.80
Oct. 3	...do	3	...	...	...	...	...	...	1	...	...	...	...	...	...	1	92.50	52	72.88
Nov. 16	....	6	...	...	...	...	...	...	...	...	...	...	...	1	1	2	79	20	53.98
Nov. 25	Meadowlark	4+	...	...	...	...	...	...	...	...	...	...	[1]4	...	...	4	79	20	52.96
	Total	36+	...	...	...	...	...	...	...	...	...	...	...	...	...	23	....	....	....

[1] Three of these molted before Jan. 31, 1910, and one on that date.

The nymph (Table XXXI).—On account of the sparsity of material at hand, our records on the longevity of nymphs are fragmentary. One nymph which molted from a larva about January 22, 1910, was alive on April 6, 1910, when it was put on a host. This individual had lived 74 days, which is the longest period recorded by us. One nymph which molted February 15, 1910, died 16 days later. Two

other lots lived from 16 to 55 days, at the end of which time they were put on hosts.

Nymphs were found to attach readily to a bovine host very soon after being applied. Attempts to get collected nymphs which were partially engorged to reattach to cattle and guinea pigs were not successful. Similar results were obtained when attempts were made to attach to rabbits and cattle nymphs which had very recently molted from the larval stage. In the three lots of nymphs the engorgement of which is recorded in the accompanying table the shortest period of engorgement was 5 days, the longest 8 days, and the weighted average 6.9 days. All of the specimens were fully engorged when they dropped.

TABLE XXXI.—*Engorgement of nymphs of Hæmaphysalis chordeilis.*

Date nymphs applied.	Host.	Number.	Nymphs dropped—Days following application.				Total number dropped.
			5	6	7	8	
1909.							
Nov. 3	Bovine	4			3	1	4
Nov. 30	do	4				2	2
Nov. 28, 29	do	5	1	2			3

The shortest molting period for nymphs in the 13 cases observed was 26 days. During this period the mean temperature was 68.05° F. and the total effective temperature 651° F. The longest molting period was 186 days at a mean temperature of 60.54° F. The lots of collected individuals varied from one-tenth to fully engorged. None of the specimens under one-half engorged was observed to molt to adults. The temperatures given are those recorded at the Dallas laboratory from the date the ticks were collected to the date when the first tick molted.

The adult.—Of a lot consisting of 4 males and 3 females which became adult between May 5 and 10, 1910, 2 individuals of each sex were placed on hosts, 2 males and 1 female being kept for a longevity test. One male and the female died on August 18, 1910, having lived about 100 days. The last male lived until March 11, 1911, or a period of 305 days. A female in another lot was found to live between 131 and 166 days after molting, and in a third lot a male lived between 97 and 127 days. Unengorged adults remain inactive for long periods when kept in a tube, and it is sometimes difficult to induce them to crawl. One female which was fully engorged but not fertilized lived 172 days, no eggs being deposited.

A male and a female were placed on a bovine April 30, 1910. The female was found to be attached when examination was made 6 hours later. The male failed to attach as did also two other males

applied several days afterwards. The female, however, began to fill with blood and 19 days later dropped rather well engorged. This female did not deposit eggs but lived 172 days, as noted above. Attempts to get adults to attach to a hen were unsuccessful.

No observations have been made on mating, nor have the periods of preoviposition and deposition been determined. The number of eggs deposited has not been determined as yet.

LIFE CYCLE.

Larvæ may live for at least 39 days and probably much longer; they engorge in from 5 to 12 days and molt in the summer as soon as the fourteenth day after dropping and as long as the ninety-second day after dropping in the winter. A total effective temperature of 505° F. is required for this transformation. One nymph lived for at least 74 days. Nymphs may become engorged in 5 days during the last of November. Molting to adults occurred in as short a period as 26 days after dropping and during the winter a molting period of 186 days was recorded. A total effective temperature of 651° F. appears to be required to produce the nymphal molt. Males may live 305 days and females as long as 131 days.

Most of our collections have been made between November and April. During this period all stages have been taken on wild bird hosts, the larvæ and nymphs being very abundant. No doubt they are present on hosts in Texas throughout the year. In Vermont, where the species has appeared as a pest to turkeys, adults and immature ticks were found in abundance in June.

ECONOMIC IMPORTANCE.

The bird tick has attracted attention as an economic species only in a few instances. In 1906 a specimen was received by the Bureau of Entomology from Taftsville, Vt., with the statement that it was found attacking a turkey. This species was not again heard of as a pest until June, 1909, when the attention of Dr. Philip B. Hadley, of the Rhode Island Agricultural Experiment Station, was called to a flock of young turkeys which were being killed by this tick at Norwich, Vt. The parasite appeared on turkeys on two farms in that locality. Dr. Hadley states that on one farm 40 out of a flock of 46 turkeys died before the ticks were finally destroyed by hand picking. Numerous adult and immature ticks were found to be attached to the hosts, principally on the necks of the birds. Dr. Hadley informed us that apparently none of these ticks was present in the vicinity of Norwich during 1910.

It is doubtful if these ticks ever become so numerous on wild birds as to cause their death, though they frequently appear in great num-

bers on quail and meadowlarks. Turkeys ranging over fields where wild birds are numerous are quite likely to become infested and thus bring the ticks into the poultry yards.

NATURAL CONTROL.

On account of the fact that this appears to be principally a bird-infesting species, there is undoubtedly a large mortality due to their destruction by the host.

ARTIFICIAL CONTROL.

This species has not been studied sufficiently to warrant any statement regarding control. It has been reported by Dr. Hadley that the ticks are exceedingly hard to kill by the application of such substances as kerosene and lard. He states that hand picking was the only method of control found to be effective against the ticks where they appeared as a pest on a farm at Norwich, Vt. A knowledge of the relation between the wild bird hosts and domestic turkeys may possibly suggest some preventive measure.

Genus RHIPICEPHALUS Koch.

Only one species of the genus Rhipicephalus occurs in the United States and that only in the extreme southern part of Texas. The genus, however, is a large one, as many as ten species being recorded by Howard (1908) as occurring in Africa alone. The members of this genus are also of considerable economic importance, five species being known to be active agents in the transmission of African coast fever, a highly fatal disease of cattle. One of these five also transmits biliary fever of horses, mules, and donkeys. A sixth species transmits ovine piroplasmosis in southern Europe, while in the Old World a seventh, the species which we have studied and consider here, transmits canine piroplasmosis.

Most of the species drop to pass their molts, but two, *R. evertsi* and *R. bursa*, pass the first molt while on the host.

Observations on the biology of the African species have been published by Lounsbury (1900b, 1905), Theiler (1905, 1909), and Howard (1909). Observations on *R. bursa* have been reported by Motas (1903).

THE BROWN DOG TICK.

Rhipicephalus sanguineus (Latreille) (*texanus* Banks).

The common name of *Rhipicephalus sanguineus* (brown dog tick) is taken from its color and the fact that the dog is its principal host.

DESCRIPTIVE.

Adult (Pl. VI, figs. 13–17).—Males from 2 by 1.25 to 3 by 1.5 mm. Females, unengorged, 1.5 by 1 mm. to 3 by 1.75 mm.; engorged, 6 by 4 by 1.5 mm. to 11 by 7 by 4.5 mm. The males and females are reddish brown, without markings, the legs being somewhat paler.

Nymph (Pl. VI, fig. 12).—Unengorged, about 0.94 by 0.57 mm.; engorged, 2.5 by 1.5 by 1 mm. to 3.5 by 2 by 1 mm. Color, unengorged, reddish brown; engorged, dark gray, some with a pink tinge and many whitish due to the engorgement of lymph; smooth, shining. Capitulum 0.244 mm. long (from tip of hypostome to base of emargination of scutum); scutum 0.451 mm. long by 0.462 mm. wide.

Larva (Pl. VI, figs. 10, 11).—Unengorged, about 0.457 by 0.328 mm.; engorged, about 1.5 by 0.88 mm. Color, unengorged, light brown; engorged, dark gray; capitulum 0.116 mm. long (from tip of hypostome to base of emargination of scutum); scutum 0.212 mm. long by 0.301 mm. wide.

Egg.—The average size of 10 eggs was 0.43 by 0.37 mm.; ellipsoidal, dark brown, shining, smooth.

HOST RELATIONSHIP.

Although this tick infests principally the dog it appears to attach to numerous hosts, among which the following have been reported: Fox, and other canines, cat, ox, horse, hare, dromedary, camel, sheep, goat, birds, and also one or two species of reptiles.

In extensive collections made by agents of this bureau in Texas and Mexico, however, the species has been taken from the dog only. Newstead reports that in Jamaica it is common on the ox as well as the dog and that it was also found on the horse. In one instance two slightly engorged nymphs attached between the fingers of one hand of one of the authors after he had been collecting specimens from dogs.

In regard to the position of attachment, Christophers, as well as the writers, has observed that the adults frequently attach to the inside of the dog's ears, even deep down in the meatus. Christophers, Nuttall, a correspondent of Newstead, and the writers have observed that they frequently attach between the toes and that they may be found there in clusters of 3 or 4. The writers have found the females to engorge to repletion between the toes of puppies. This position is readily accessible to the ticks and infestation may occur without being suspected, as even the engorged females are often obscured from view. Many larvæ and nymphs of this as well as other species attach and engorge in the little pocket on the posterior border of the ear. In the immature stages it appears to prefer to attach in the long hair on the neck rather than in the ears, the ticks frequently being found in cluster of a dozen or more. All three stages may, however, attach to almost any part of the body.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 6.)

This species is probably the most widely distributed of all the ticks, at least of the ixodid ticks, even though largely limited to the

FIG. 6.—The brown dog tick, *Rhipicephalus sanguineus:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicat the probable distribution of the species. (Original.)

Tropical and Subtropical regions. Portugal is the type locality of the species. In Europe it is also recorded from France, Italy, Sicily, Corsica, and Roumania; in Africa from Egypt, Algeria, Tunis, Nubia, Abyssinia, Zanzibar, German East Africa, Portuguese East Africa,

Transvaal, Natal, Cape Colony, Madagascar, German Southwest Africa, Kamerun, Togo, Congo, and Senegal; in Asia from Arabia, Persia, Malay Archipelago, India, and China. It has also been reported from Australia, the Philippines, and the Hawaiian Islands. In this country it has been commonly taken in southern Texas as far north as Jackson County and San Marcos in Hays County, and as far west as Del Rio. The species has been collected at several points in Mexico as far west as Torreon, in Panama, Colombia, Guiana, and Brazil, and undoubtedly occurs in all of the intervening countries. It occurs throughout the West Indian Islands, having been reported from Jamaica, Haiti, Antigua, and Dominica. Ticks from the West Indies, including Cuba, Haiti, and Curaçao Island, have been referred by Neumann to *R. bursa.*

LIFE HISTORY.

Observations on the biology of this tick have been made in India by Christophers (1907), in Jamaica by Newstead (1909), and in Texas by Hunter and Hooker (1907), and by Hooker (1908).

The egg (Table XXXII).—Christophers reports that engorged females after dropping from the host at once proceed to crawl away, climbing upward sometimes to a height of over 15 feet from the ground, into cracks and crevices. He states that it often crawls into cracks so narrow that it becomes firmly wedged in. We also have observed that there is a decided tendency for the females to crawl upward. It appears certain that the majority of females drop and deposit eggs in or near the kennel or sleeping place of the dogs.

Temperature has a very marked influence on the preoviposition period. In July and August at a mean temperature of about 85° F., oviposition began on the third day after dropping, while ticks which dropped on November 1, 2, and 3, did not begin to oviposit until the fifty-fourth, sixty-ninth, and eighty-third days, respectively, after dropping. The mean temperature during these periods was about 62° F.

The period of deposition is also decidedly affected by the temperature. This period varied from 8 to 67 days. The cool weather tends to produce intermittent deposition. The largest number of eggs recorded, 2,616, was deposited within a period of 11 days, beginning on September 5, by a tick which measured 10 by 7 by 4.5 mm. The large daily deposition and the short period required for oviposition during warm weather are noticeable characteristics of this species. Of the 12 cases in which oviposition was recorded the smallest number of eggs was 360. This was in November. The average of the 12 females was 1,601 eggs. Death usually takes place between the first and fourth days after deposition is complete.

The minimum incubation period recorded was 19 days. This record was made on eggs deposited on August 21 and kept at a mean temperature of 83.5° F. An effective temperature of 774° F. appears to be required for incubation. Christophers states that eggs hatch in 3 or 4 weeks.

TABLE XXXII.—*Incubation and larval longevity of Rhipicephalus sanguineus.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation. Maximum.	Minimum.	Average daily mean.	Total effective.
IN THE LABORATORY.								
		Days.		*Days.*	*° F.*	*° F.*	*° F.*	*° F.*
Mar. 31, 1908	May 10, 1908	41			85.0	47.0	69.00	1,066.37
Apr. 18, 1908	May 26, 1908	39	July 7, 1908.	42	87.0	47.0	72.18	1,138.25
Apr. 20, 1908	May 27, 1908	38			87.0	47.0	72.33	1,082.25
Apr. 22, 1908	May 26, 1908	35			87.0	47.0	72.05	986.25
July 7, 1908	July 27, 1908	21	Oct. 7, 1908	72	95.0	74.0	83.99	860.50
July 29, 1908	Aug. 17, 1908	20	After Sept. 10, 1908	24+	99.0	73.0	86.50	870.00
July 31, 1908	Aug. 19, 1908	20	Sept. 30-Oct. 26, 1908	42–68	99.0	73.0	86.70	874.00
Aug. 2, 1908	Aug. 22, 1908	21	Sept. 28, 1908	37	99.0	73.0	86.26	908.50
Aug. 21, 1908	Sept. 8, 1908	19	Nov. 13-26, 1908.	66–79	97.5	75.0	83.73	774.00
Aug. 25, 1908	Sept. 12, 1908	19	do	62–75	97.5	74.5	83.90	777.20
Aug. 26, 1908	Sept. 14, 1908	20	do	60–73	97.5	74.5	83.60	812.45
Oct. 21, 1908	Mar. 11, 1909	142	After Apr. 24, 1909	44+	85.0	17.0	60.88	2,314.00
Sept. 20, 1910	Nov. 12?, 1910	54 (about).	Feb. 20, 1911	100 (about)				
OUT OF DOORS.								
Apr. 13-26, 1906	May 27, 1906	45	Aug. 15, 1906	80	93.0	41.5	69.08	1,173.60
Apr. 28, 1906	May 30, 1906	33			93.0	42.0	71.72	947.76
Before May 4, 1906	June 5, 1906	33+						
May 17, 1906	June 9, 1906	24			93.8	59.2	76.90	813.60

The larva (Table XXXIII).—The longevity of larvæ in summer under the most favorable conditions was 80 days. Several lots are recorded, however, in which the longevity was much shorter, the average life being not far from 2 months. The last individuals of a lot of larvæ from eggs deposited from August 4 to 6, 1907, and which commenced to hatch August 25, died between January 3 and 10, 1908, thus having lived between 131 and 138 days. Christophers states that in nature the larvæ collect near the bottom of walls and wait for a dog to brush against the spot.

Engorgement took place in as soon as 3 days; the greatest number dropped from the third to the fifth days, and all dropped before the seventh day. Christophers found larvæ which he placed upon a dog to engorge and drop in from 3 to 4 days.

TABLE XXXIII.—*Engorgement of larvæ of Rhipicephalus sanguineus.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.									Total number dropped.
		1	2	3	4	5	6	7	8	9	
Oct. 3, 1907	Bovine	0	0	51	138	6	2	0	0	0	197
May 27, 1908	do	0	0	0	58	18	2	0	0	0	78
June 5, 1908	do	0	0	25	85	31	0	0	0	0	141

At a mean temperature of 82° F. larvæ which dropped engorged on June 18, 1908, commenced to molt on the sixth day, while ticks which dropped October 6–8 did not commence to molt until the twentieth and twenty-third days. An effective temperature of 235° F. was required. Christophers states that 9 or 10 days are required for molting.

The nymph (Tables XXXIV, XXXV).—In order to determine the longevity of nymphs, a large number which molted September 30 and 31, 1907, were kept in a tube in the laboratory on moist sand. On March 5, 1908, 12 were alive, while on March 28 only one survived. On April 1 the remaining tick was found to be dead. Thus all of this lot were dead in 6 months from molting. Four of 6 nymphs which molted June 8 and 9, 1908, were dead August 3; on August 10 one was still alive, but on August 20 the last one was dead. Thus in summer nymphs lived but two and one-half months at the longest. Of a lot of 23 nymphs, slightly to one-third engorged, that were collected on dogs, October 29, 1910, 2 lived until April 5, 1911, or 158 days.

Engorgement was found to take place as soon as 4 days after attachment. The greatest number dropped on the fifth and sixth days; all were engorged and had left the host by the tenth day.

TABLE XXXIV.—*Engorgement of nymphs of Rhipicephalus sanguineus.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
Nov. 7, 1907	Bovine	0	0	0	3	10	2	0	1	0	0	16
July 13, 1908	do	0	0	0	3	10	15	5	5	1	0	39

In summer, when the mean temperature was between 84.65° F. and 85.42° F., molting has been observed to take place as soon as the twelfth day. A total effective temperature of 500° F. is required to produce this molt. The molting period of nymphs which form males appears to be the same as for those which form females. Christophers found 15 days to be required for molting.

TABLE XXXV.—*Molting of engorged nymphs of Rhipicephalus sanguineus.*

[♂=Male. ♀=Female.]

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.														
			12	13	14	15	16	17	18	19	20	23	26	27	29	53	56
Sept. 22, 1907	Dog	1	...	...	1♀	...	...	...	...	...	...	...	...	...	...	...	...
Oct. 27, 1907	do	1	...	...	...	...	...	...	...	...	...	1♀	...	...	...	...	...
Nov. 11, 1907	Bovine	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nov. 12, 1907	do	6	...	...	...	...	...	...	...	...	...	...	...	...	...	2♀	1♂
Apr. 22, 1908 [1]	Dog	11	...	...	...	...	...	...	...	...	...	...	6	4	1	...	...
July 17, 1908	Bovine	3	1♂	1♂	...	...	1♀	...	...	...	...	...	...	...	...	...	...
July 18, 1908	do	10	...	3♂ 2♀	3♂ 2♀	...	...	...	...	...	...	...	...	...	...	...	...
July 19, 1908	do	15	2♀	5♂ 4♀	1♂ 2♀	...	...	...	...	...	...	...	...	...	...	...	...
July 20, 1908	do	5	1♀	1♂	...	...	2♂	...	...	...	...	...	...	...	...	...	...
July 21, 1908	do	3	1♀	1♀	...	...	...	...	...	...	...	...	...	...	...	...	...
Aug. 17, 1908 [2]	Dog	100	...	...	7♂ 19♀	8♂ 14♀	9♂ 4♀	3♂ 2♀	1♀	...	...	...	...	...	...	...	...
Aug. 18, 1908 [3]	do	100	...	3♂ 7♀	2♂ 5♀	6♂ 9♀	4♀	3♂ 4♀	4♂ 3♀	1♂ 1♀	1♂	...	...	...	...	...	...
Nov. 29, 1909	do	64	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Total	322	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.								Number molted.			Temperature from dropping to date first tick molted.		
			57	58	59	73	122	125	127	129	Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
														°F.	°F.	°F.
Sept. 22, 1907	Dog	1	...	...	...	...	...	...	...	...	...	1	1	...	...	...
Oct. 27, 1907	do	1	...	...	...	...	...	...	...	...	...	1	1	...	...	...
Nov. 11, 1907	Bovine	3	1♂	1♀	...	...	...	...	...	...	1	1	2	...	...	...
Nov. 12, 1907	do	6	1♀	...	1♀	1♀	...	...	...	...	2	4	6	...	...	...
Apr. 22, 1908 [1]	Dog	11	...	...	...	...	...	...	...	...	...	...	11	86.0	47.0	70.39
July 17, 1908	Bovine	3	...	...	...	...	...	...	...	...	2	1	3	95.0	76.5	84.65
July 18, 1908	do	10	...	...	...	...	...	...	...	...	6	4	10	95.0	76.5	84.70
July 19, 1908	do	15	...	...	...	...	...	...	...	...	6	8	14	95.0	76.5	84.69
July 20, 1908	do	5	...	...	...	...	...	...	...	...	3	1	4	95.0	76.5	84.92
July 21, 1908	do	3	...	...	...	...	...	...	...	...	0	2	2	95.0	77.0	85.42
Aug. 17, 1908 [2]	Dog	100	...	...	...	...	...	...	...	...	27	40	67	96.0	75.5	83.90
Aug. 18, 1908 [3]	do	100	...	...	...	...	...	...	...	...	20	33	53	93.0	75.5	83.55
Nov. 29, 1909	do	64	...	...	...	...	10	3	2	2	...	...	17	92.0	20.0	55.97
	Total	322	...	...	...	...	...	...	...	...	67	96	191	...	...	...

[1] Collected at Brownsville, Tex.
[2] Collected at Brownsville, Tex.; 27 of these nymphs were parasitized.
[3] Collected at Corpus Christi, Tex.; 40 of these nymphs were parasitized.

The adult (Table XXXVI).—Of 163 adults which were observed to molt from nymphs, 96, or 58.9 per cent, were females. The greatest adult longevity observed by us was between 204 and 214 days. This record was made on a lot of 13 males and 15 females which molted from nymphs September 1, 1908, and were kept in a tube on moist sand in the laboratory. On March 24, 1909, or after 204 days, a male and a female were alive. These were both dead on April 3, 1909. Other specimens which became adult in early September were found to live nearly as long as the lot above referred to. Several lots of ticks

which became adult late in July and early in August lived from 77 to 158 days. One lot of ticks which became mature on May 18 to 21, 1908, lived about 3 months. Of a lot of 91 individuals collected on hosts on July 21, 1909, 4 were still alive December 15, 1909, having lived at least 147 days. However, a large percentage of the adults collected from dogs in the summer die within a month or 6 weeks. The longevity of the sexes appears to be about the same. We have observed unengorged adults crawling from between the cracks in floors. At Corpus Christi, Tex., they were found in considerable numbers in the cracks of a porch floor where dogs frequently slept. Christophers reports that after molting adults crawl into straw or similar material and there await the host.

Mating, which takes place on the host, may commence as soon as the fourth day after attachment and often continues until the engorged female drops. The male sometimes drops with the female or detaches soon after and goes in search of another mate. In one instance a male and partially engorged female in a tube on sand were observed apparently in copulation.

On November 19, 1909, Mr. J. D. Mitchell collected a male *Amblyomma americanum* in coitu with a female of this species on a dog at Corpus Christi, Tex. The mouth parts of the male were again inserted in the genital opening of the female when the ticks were put in a vial and they remained in this relation for at least fifteen minutes, when they were packed for mailing. Subsequently the female, which was partially engorged, deposited fertile eggs.

Fertilized females were found to engorge more rapidly than unfertilized ones. In one instance a female engorged in 6 days, while in several instances females remained attached for from 44 to 50 days, and even then were not fully engorged when they dropped. It is quite apparent that fertilization is an important factor in the period required for engorgement, as in the short period mentioned above the ticks mated on the fourth day after attachment, while in the extremely long periods mentioned mating did not occur at all.

TABLE XXXVI.—*Engorgement of females of Rhipicephalus sanguineus.*

Adults applied.	Host.	Females dropped engorged.	Period of attachment.	Size engorged.
			Days.	
Oct. 26, 1907	Dog	Nov. 2, 1907	7	9.5 by 6.5 by 4 mm.
Do	do	Nov. 3, 1907	8	11 by 7 by 4 mm.
Jan. 4, 1908	Bovine	Feb. 17, 1908	44	
Do	do	Feb. 18, 1908	45	8 by 5 by 3 mm.
Do	do	Feb. 23, 1908	50	
Apr. 4, 1908	do	Apr. 10, 1908	6	9 by 6 by 3 mm.
Do	do	Apr. 11, 1908	7	8 by 5 by 2 mm.
Do	do	Apr. 12, 1908	8	6 by 4 by 1.5 mm.
Do	do	do	8	8 by 5 by 2 mm.

Males do not appear to remain attached to the host after the females have dropped. If they do not drop with the females they start out in search of another mate; in this search they frequently go from one dog to another. Their longevity on the host is at least several months.

LIFE CYCLE.

Oviposition may commence as soon as the third day, and as many as 2,616 eggs may be deposited. In August eggs may hatch in 19 days, an accumulated effective temperature of 774° F. appearing to be required for their incubation. Larvæ may live for 131 to 138 days while waiting for a host; they may engorge in 3 days and molt in 6 days. A total effective temperature of 235° F. is required to produce this molt. During the winter nymphs may live for 6 months; they may engorge in 4 days after attaching to a host. In summer they may molt in 12 days, a total effective temperature of 500° F. being required. Adults may live as long as 204 days; they may become engorged in 6 days after attaching to an animal; fertilization takes place on the host. All stages of the tick may be found at any time during the year. However, they are less numerous after long continued drought.

ECONOMIC IMPORTANCE.

This species is perhaps the most important tick that attacks the dog. While restricted in its distribution to the Tropical and Subtropical life zones, it is widely distributed over the Old and New Worlds, in both of which it is the source of great annoyance to dogs. Its particular importance, however, lies in the fact that it is the active agent in the transmission of canine piroplasmosis. Fortunately this disease has not been introduced into the New World. It is, however, prevalent in certain sections of the Old World, particularly in India. The disease also occurs in South Africa, where it has been shown by Lounsbury to be transmitted by *Hæmaphysalis leachi.*

NATURAL CONTROL.

While no particular investigation has been made of the predaceous enemies of the species, those attacking the cattle tick undoubtedly destroy this tick also.

In 1908 a parasite was discovered which destroys large numbers of this species while in the nymphal stage. This parasite, the second recorded as attacking ticks, was described by Dr. L. O. Howard (1908) as *Hunterellus hookeri.* In order to determine the percentage of parasitism, 100 engorged nymphs were collected at Brownsville, Tex., August 17, 1908, and an equal number from Corpus Christi on August 18, 1908. These were isolated in pill boxes in lots of 10 each and kept on moist sand. Of the 100 collected at Brownsville, 27

were parasitized, 67 produced adult ticks (27 males and 40 females), and 6 did not produce either ticks or parasites. Of the 100 collected at Corpus Christi, 40 were parasitized, 53 produced adult ticks (20 males and 33 females), and 7 produced neither ticks nor parasites. Although a number of lots of nymphs have been collected which have shown no signs of parasitism, the insect is undoubtedly an important enemy of this tick. The parasite appears to be more restricted in its distribution in the United States than is the tick. Recently Mr. C. W. Howard has reared this parasite in Portuguese East Africa from the same host.[1]

ARTIFICIAL CONTROL.

Spraying frequently with, or dipping in a solution of one of the several coal-tar products that are now on the market should be practiced when this tick becomes a pest. It is important that the kennels or other sleeping places of dogs be kept scrupulously free from filth and that they be thoroughly sprayed at frequent intervals with some strong disinfectant. The destruction of roving and uncared-for dogs also greatly aids in the control of this tick.

Genus MARGAROPUS Karsch.

Of all the ticks those belonging to the genus Margaropus are the most important economically, owing to the part which they play in the transmission of Piroplasma and Anaplasma, which cause splenetic fever in bovines. Neumann recognizes 5 varieties of *annulatus*, all of which appear to transmit piroplasmosis. In addition to *annulatus*, we have studied the variety *australis*. One variety, *decoloratus*, is known to transmit *Spirochæta theileri*, which is the cause of a disease of cattle in South Africa. All of the ticks of this genus pass both molts upon the host.

THE NORTH AMERICAN CATTLE TICK.[2]

Margaropus annulatus (Say).

The common name of this species comes from the fact that it is the most common and important tick attacking cattle in North America.

DESCRIPTIVE.

Adult (Plate VIII, figs. 1, 6–11).—Males from 2 by 1.25 mm. to 2.4 by 1.3 mm. Females, unengorged, about 3 by 1.75 mm.; engorged, from 10.5 by 6 by 4.5 mm. to 14 by 9 by 6 mm.

Nymph (Plate VIII, figs. 3–5).—Unengorged, about 1.5 by 0.6 mm.; engorged, about 3 by 2.8 by 0.8 mm. Color, unengorged, light

[1] More recent studies of this parasite have been published by Wood (1911).

[2] The data on the cattle tick are presented in order that its biology may be compared with that of the other ticks. For more detailed information see Bulletin 72 of this bureau. The discovery of the fact that *Dermacentor venustus* conveys the infection of Rocky Mountain spotted fever has made it desirable that the above name be applied in place of that of North American fever tick, used in Bulletin 72.

yellowish or grayish brown; capitulum and shield light reddish brown; legs pale yellowish brown; engorged, grayish blue. Capitulum 0.296 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.478 mm. long by 0.455 mm. wide.

Larva (Plate VIII, fig. 2).—Unengorged, about 0.547 by 0.413 mm.; engorged, 1.5 by 0.75 mm. Color unengorged, capitulum and scutum dark reddish, legs a shade lighter, body almost colorless; engorged, light yellowish gray. Capitulum 0.148 mm. (from tip of palpi to base of emargination of scutum); scutum 0.296 mm. long by 0.341 mm. wide.

Egg.—Ellipsoidal, deep yellowish brown, shining, smooth. The average size of 10 specimens measured was 0.542 by 0.418 mm.

HOST RELATIONSHIP.

The type host is the Virginia white-tailed deer, *Cervus virginianus* Boddoert [=*Odontocœlus americanus* (Erxleben)]. Of the undomesticated animals the deer is the only host known.

Bovines are the principal hosts of the species, but the tick also commonly attaches to horses and mules, and occasionally to sheep and goats. Only 4 engorged females have been taken by the writers from dogs, although numerous dogs have been examined and many attempts to induce this tick to attach to them have been made. Attachment to a human host very rarely takes place.

GEOGRAPHICAL DISTRIBUTION.

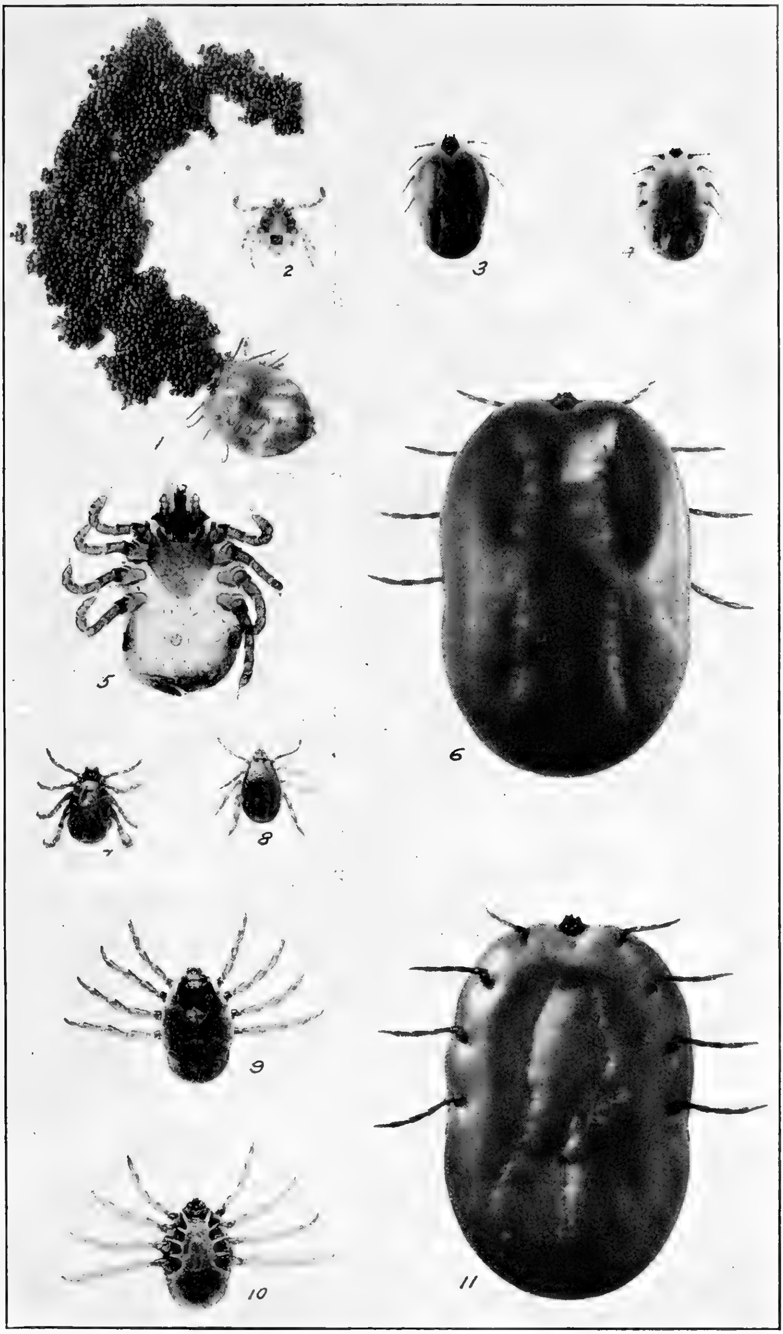
(Fig. 7.)

Florida is the type locality. This species is limited in distribution to the Lower Austral and a very small portion of the Upper Austral and Tropical Zones. The species occurs in greatest abundance in the humid or Austroriparian division of the Lower Austral Zone. It is known to occur only in the southern United States and Mexico, although it has been carried from this territory upon the host. The quarantine placed upon southern cattle by the United States Department of Agriculture now prevents its introduction into the Northern States.

LIFE HISTORY.

Owing to the economic importance of this species its life history and habits are better known than those of any other tick. Studies of its biology have been made by Curtice (1891), Morgan (1898), Newell and Dougherty (1906), Hunter and Hooker (1907), Cotton (1908), Graybill (1911), and others.

The egg (Tables XXXVII–XXXIX).—During the warmer months of the year oviposition commences on the second or third day after dropping. Occasionally eggs may be deposited on the day following dropping. During the winter months the preoviposition period is



THE NORTH AMERICAN CATTLE TICK, MARGAROPUS ANNULATUS.

Fig. 1.—"Deposited-out" female with eggs. Fig. 2.—Unengorged larva. Fig. 3.—Engorged nymph, dorsal view. Fig. 4.—Engorged nymph, ventral view. Fig. 5.—Unengorged nymph (balsam mount). Fig. 6.—Fully engorged female, dorsal view. Fig. 7.—Male, ventral view. Fig. 8.—Male, dorsal view. Fig. 9.—Unengorged female, dorsal view. Fig. 10.—Unengorged female, ventral view. Fig. 11.—Fully engorged female, ventral view. (Original.)

greatly lengthened. In one case a tick which dropped on November 20 did not begin depositing until January 25, giving a preoviposition period of 66 days. As a rule, however, the adults are killed by temperatures which are sufficiently low to retard deposition to this extent. The following table, which is based upon ticks which

FIG. 7.—The North American cattle tick, *Margaropus annulatus:* Distribution in the United States. (Original.)

dropped from the host, shows an oviposition period of from 1 to 3 days and a deposition period of from 8 to 16 days. The average number of eggs deposited by the 10 ticks was 3,424 and the maximum number deposited by one female was 4,547.

TABLE XXXVII.—*Oviposition of Margaropus annulatus engorged on bovine.*

Date engorged female dropped.	Size.	Number of eggs deposited—days following dropping.										
		1	2	3	4	5	6	7	8	9	10	11
1908.												
Aug. 3	12 by 7.5 by 6 mm	0	0	481	676	754	535	384	326	194	105	53
Aug. 4	14 by 9 by 6 mm	0	21	596	857	711	708	576	443	166	264	112
Do...	13 by 7.5 by 5.5 mm	0	0	297	560	457	514	511	442	372	241	141
Do...	12.5 by 7 by 5 mm	0	0	494	511	320	500	381	272	159	36	0
Aug. 6	12.5 by 8 by 5.5 mm	0	86	386	338	427	393	257	139	57	12	10
Do...	13 by 8 by 5.5 mm	0	280	420	335	493	663	540	330	154	96	32
Aug. 7	13.9 by 5 by 5 mm	35	314	431	425	771	658	576	272	222	76	43
Aug. 6	13 by 8 by 6 mm	0	0	402	481	612	356	272	580	228	128	17
Aug. 8	13.5 by 8.5 by 6 mm	0	177	441	602	729	978	491	455	245	150	61
Do...	12.5 by 8 by 5.5 mm	0	60	302	361	416	431	353	336	228	156	148

Date engorged female dropped.	Size.	Number of eggs deposited—days following dropping.										Total number of eggs.
		12	13	14	15	16	17	18	19	20	21	
1908.												
Aug. 3	12 by 7.5 by 6 mm	30	23	4	0	0	4	2	0	([1])	....	3,571
Aug. 4	14 by 9 by 6 mm	61	19	7	6	0	0	0	0	0	[2] 0	4,547
Do...	13 by 7.5 by 5.5 mm	60	34	21	4	3	4	0	0	0	([1])	3,661
Do...	12.5 by 7 by 5 mm	[3] 0	......	......	......	......	......	......	......	....	....	2,673
Aug. 6	12.5 by 8 by 5.5 mm	5	2	15	0	0	[4] 0	......	......	....	....	2,127
Do...	13 by 8 by 5.5 mm	12	11	8	0	([1])	......	......	......	....	....	3,374
Aug. 7	13.9 by 5 by 5 mm	24	5	([1])	......	......	......	......	......	....	....	3,852
Aug. 6	13 by 8 by 6 mm	32	5	0	0	0	0	0	0	([1])	....	3,113
Aug. 8	13.5 by 8.5 by 6 mm	41	19	9	3	0	([1])	......	......	....	....	4,401
Do...	12.5 by 8 by 5.5 mm	60	33	8	19	5	7	0	0	0	[5] 0	2,923
Average		......	......	......	......	......	......	......	......	....	....	3,424

[1] Died.
[2] Died on 27th day.
[3] Not completely deposited; appears injured.
[4] Apparently injured; died on 25th day.
[5] Died on 23d day.

The shortest period which we have observed to be required for incubation was 19 days and the longest was 202 days. During the former period the mean temperature was 87° F., the maximum being 102.5° F. and the minimum 71° F. During the latter period the mean temperature was 54.26° F., while the maximum was 92.5° F. and the minimum 14° F. In the laboratory in August eggs hatched as soon as the twentieth day after deposition, an effective temperature of 820° F. being required for their incubation.

TABLE XXXVIII.—*Incubation of Margaropus annulatus in the laboratory.*

Eggs deposited.	Hatching began.	Minimum incubation period.	Temperature during incubation.			
			Maximum.	Minimum.	Average daily mean.	Total effective temperature.
1908.	1908.	*Days.*	*° F.*	*° F.*	*° F.*	*° F.*
May 22	June 19	29	91.5	68	79.76	1,065
June 26	July 18	24	94	70.5	82	897
July 15	Aug. 6	22	95	76.5	85.15	969.50
Aug. 7	Aug. 26	20	99	73	85.51	850.25
Aug. 9	Aug. 29	21	96.5	73	84.76	877
Aug. 11	Aug. 30	20	96.5	75	84.88	837.50
Aug. 13	Sept. 2	21	96	75	84.62	874
Aug. 16	Sept. 4	20	96	75	84.01	820.25

TABLE XXXIX.—*Preoviposition, incubation, and longevity of larvæ of Margaropus annulatus out of doors.*

Date females collected.	Oviposition began.	Preoviposition period.	Hatching began.	Minimum incubation period.	All larvæ dead.		Larval longevity.
					Date.	Period from dropping of female.	
		Days.		*Days.*		*Days.*	*Days.*
Aug. 6, 1906	Aug. 19, 1906	13	Sept. 10, 1906	23	Apr. 9, 1907	246	211
Mar. 20, 1907	Mar. 24, 1907	4	May 30, 1907	68	July 20, 1907	122	51
May 8, 1907	May 12, 1907	4	June 22, 1907	42	Aug. 27, 1907	111	66
July 3, 1907	July 6, 1907	3	July 27, 1907	23	Oct. 5, 1907	94	69
July 31, 1907	Aug. 3, 1907	3	Aug. 26, 1907	24	Dec. 10, 1907	132	106
Aug. 21, 1907	Aug. 25, 1907	4	Sept. 21, 1907	28	May 22, 1908	275	244
Sept. 25, 1907	Sept. 30, 1907	5	Mar. 27, 1908	180	June 30, 1908	279	95
Mar. 20, 1908	Mar. 29, 1908	9	May 22, 1908	55	Aug. 13, 1908	146	83
July 1, 1908	July 5, 1908	4	July 28, 1908	24	Nov. 8, 1908	130	103
July 21, 1908	July 25, 1908	4	Aug. 18, 1908	25	Mar. 31, 1909	253	225
Aug. 12, 1908	Aug. 14, 1908	2	Sept. 9, 1908	27	May 13, 1909	274	246
Sept. 16, 1908	Sept. 23, 1908	7	Dec. 15, 1908	84	May 4, 1909	230	140
Oct. 5, 1908	Oct. 17, 1908	12	Mar. 23, 1909	158	July 5, 1909	273	104
May 24, 1909	May 29, 1909	5	June 28, 1909	31	Aug. 15, 1909	83	48
Aug. 2, 1909	Aug. 5, 1909	3	Aug. 27, 1909	23	Sept. 25, 1909	54	29
Sept. 6, 1909	Sept. 10, 1909	4	Oct. 14, 1909	35	May 7, 1910	243	205
Sept. 27, 1909	Oct. 4, 1909	7	Mar. 4, 1910	152	June 12, 1910	258	100
Nov. 8, 1909	Nov. 20, 1909	12	May 24, 1910	186	July 21, 1910	255	58

The larva (Tables XXXIX, XL).—Larvæ have been found to live as long as 246 days during cool weather and during midsummer from a few days to 100 days. The longevity of the larvæ given in Table XXXIX is based upon the entire number of eggs deposited by a female, the period being figured from the day the hatching of the lot began until all larvæ in the lot were dead. All were kept in large tubes with cloth tops and soil bottoms. These were set in the ground beneath a thin burlap shelter; otherwise the conditions were normal.

Molting begins from the fifth to the twelfth day after application to a host and usually all larvæ molt to nymphs within 16 days after attachment.

The nymph (Table XL).—After the larval skin splits the nymph crawls out and reattaches close to the old point of attachment. The larval skin sometimes remains attached to the host for several days. Nymphs have been found to become engorged and molt to adults as soon as 5 days after the larval molt. The period from attachment to the beginning of molting varies from 13 to 18 days. The length of the molting period of nymphs which become males is frequently from 1 to 3 days shorter than for those which become females.

The adult (Table XL).—The number of males and females which transform from a given lot of nymphs is approximately the same. As has been stated, the males usually appear from 1 to 3 days before the females. Both sexes crawl from the nymphal skin after it has been ruptured and reattach in the immediate vicinity of the old skin, which frequently remains attached to the host for several days. Before starting in search of mates the males usually feed

for a short time, during which the chitin hardens; they then find females, with which they mate, or they may attach beneath engorged nymphs and await their transformation.

Females have been found to engorge and begin dropping on the fourth day after molting. The longest period observed between the first nymphal molt and the dropping of the first female was 14 days. In a large number of infestations the minimum parasitic period (from the application of larvæ to the beginning of dropping of females) was 20 days. The maximum parasitic period was 59 days and the average was 32 days.

TABLE XL.—*Parasitic period of Margaropus annulatus on bovines.*

Larvæ applied.	First molt.		Second molt.		Adults dropped.			Period, adult stage.		Period, attachment to dropping.		
	Date.	Period after application.	Date.	Period after first molt.	First.	Last.	Total number.	Minimum.	Maximum.	Maximum.	Minimum.	Average.
1907.	1907.	*Days.*	1907.	*Days.*	1907.	1907.		*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Feb. 16	Feb. 23	7	Mar. 3	8	Mar. 12	Mar. 22	72	9	19	34	24	29
July 12	July 18	6	July 27	9	Aug. 1	Aug. 9	89	5	13	28	20	24
1910. Oct. 14	1910. Oct. 20	6	1910. Oct. 29	9	1910. Nov. 5	1910. Nov. 21	712	7	23	38	22	30
Dec. 27	1911. Jan. 8	12	1911. Jan. 14	6	1911. Jan. 23	1911. Feb. 8	760	9	25	43	27	35
1911. Mar. 15	Mar. 23	8	Apr. 1	9	Apr. 10	Apr. 23	212	9	22	39	26	32.5

LIFE CYCLE.

At Dallas, Tex., the larvæ hatching from the entire mass of eggs deposited by a female have been found to survive for a period of 246 days from the time hatching began. The larvæ begin molting from the fifth to the twelfth day after application to a host. The nymphs become engorged and begin molting from the thirteenth to the eighteenth day. Adults sometimes engorge and drop as soon as the fourth day after the nymphal molt. The minimum period from the attachment of the larvæ to the dropping of the first engorged female was 20 days and the maximum period was 59 days. Oviposition may commence on the day following dropping, but usually the preoviposition period is at least 3 days. In the summer, when the mean temperature was 87° F., hatching began on the nineteenth day after the beginning of deposition. An effective temperature of at least 820° F. is required for incubation. The period from the dropping of the engorged females to the death of the last larvæ, or the nonparasitic period, varies from 28 days in summer to 279 days in fall, winter, and spring. In the southern part of the United States all stages of this tick may be found on hosts at any time during the year.

ECONOMIC IMPORTANCE, NATURAL CONTROL, AND ARTIFICIAL CONTROL.

These subjects are treated in detail in Bulletin 72 of the Bureau of Entomology and in Farmers' Bulletin 378 of the United States Department of Agriculture.

THE AUSTRALIAN CATTLE TICK.

Margaropus annulatus australis (Fuller).

The common name, Australian cattle tick, is taken from the scientific name, the latter having been given because the type material was collected in Australia.

DESCRIPTIVE.

Adult.—Males 2.5 by 1.25 mm. Females, unengorged, about 2.5 by 1.25 mm.; engorged, 10 by 7.5 by 5 mm. to 12 by 8.5 by 6 mm. The coloration is very similar to that of *annulatus* proper.

Nymph.—Unengorged, about 1.25 by 0.75 mm.; engorged, about 3 by 2.75 mm. Color very similar to *M. annulatus.* Capitulum 0.35 mm. long (from tip of hypostome to base of emargination of scutum); scutum 0.48 mm. long by 0.436 mm. wide.

Larva.—Unengorged, about 0.46 by 0.36 mm.; engorged, about 1.4 by 0.9 mm. Color as in *M. annulatus* proper. Capitulum 0.152 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.275 mm. long by 0.356 mm. wide.

Egg.—Ellipsoidal, dark brown, shining, smooth. The average size of 10 eggs measured was 0.531 by 0.406 mm.

HOST RELATIONSHIP.

The host relations of this variety are about the same as those of *annulatus* proper. Cattle are the principal hosts, but the horse, goat, sheep, dog, rabbit (*Lepus cuniculus domesticus*), and man (for the larvæ) are reported as hosts by Rohr (1909), who has studied this variety in Brazil. Lahille (1905) reports that in Argentina he has found this tick on horses as well as cattle and has taken it once from the hide of a marsh deer, *Blastocerus dichotomus* Illiger (*B. paludosus* Desmarest). Newstead (1909), who has studied the ticks of Jamaica, states that in several instances mature specimens of both sexes were found on the dog. He reports it to be a general belief in Jamaica that the larva of this variety will attack any vertebrate animal that comes its way, but fails to present instances. He further states that the larva is a great pest to man. The habit of the larva of attaching to man as reported by Newstead and by Rohr appears to be similar to that of *Margaropus annulatus decoloratus* and unlike *M. annulatus* proper, which as a larva never attaches to a

human host. The hosts reported by Neumann are cattle, horse, sheep, dog, and deer. One of the authors (Bishopp) found this tick in great numbers on cattle at Tampico, Mex., but very few were taken on horses. Mr. G. N. Wolcott has collected it on both horses and cattle in the Province of Pinar del Rio, Cuba.

GEOGRAPHICAL DISTRIBUTION.

This variety, which Neumann considers as including *microplus*, has a wide distribution. It undoubtedly occurs in all of the countries of South America, having been reported from British Guiana, Brazil, Paraguay, Uruguay, Argentina, and Chile. It is known to occur as far north as Tampico, Mex., where it was found to be a bad pest. In Central America it has been reported from Guatemala, Costa Rica, and Panama. It appears to be widely distributed in the West Indies, having been reported from Cuba, Jamaica, Porto Rico, Antigua, Guadeloupe, Dominica, and Trinidad.

The variety was described from Australia, where it has quite a wide distribution. It has also been reported from the Malay Archipelago (from Borneo and Sumatra), and Lounsbury has found it, as well as another variety, *decoloratus*, to occur in Cape Colony. C. S. Banks (1904) has reported the finding of this tick upon cattle which had arrived in the Philippine Islands 26 days before. He suggests that the ticks may have attached after arriving at Manila, in which case it may occur throughout those islands. From what he says in regard to the occurrence of larvæ on and in buildings near Manila where cattle are kept, it seems quite probable that this tick occurs there.

LIFE HISTORY.

Observations on the biology of this variety have been made by Pound (1899) in Australia, Lounsbury (1905) in Cape Colony, Lignières (1900), and Lahille (1904) in Argentina, Rohr (1909) in Brazil, and Newstead (1909) in Jamaica.

The egg (Table XLI).—In one instance oviposition commenced on the day following dropping and in another on the second day. Females which dropped on April 30, 1908, and were placed out of doors in tubes on sand commenced oviposition in from 5 to 13 days. The period of deposition as observed in 5 ticks varied from 15 to 23 days. The largest number of eggs deposited by any one of 11 ticks observed was 4,459 in which instance oviposition commenced on September 4, the second day following dropping. This female, which measured 12 by 8 by 5.5 mm., was the second largest tick observed. The average number of eggs deposited, based upon the 11 ticks observed, was 3,424. Rohr reports 3,046 to have been the maximum number of eggs deposited by any tick observed by him, with 1,529 as the minimum and 2,471 as the average for some 18 ticks.

TABLE XLI.—*Incubation and larval longevity of Margaropus annulatus australis.*

IN THE LABORATORY.

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation. Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	*Days.*		*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
May 13	June 5	24	....	....	88.5	65.0	77.76	834.25
May 14	June 6	24	....	....	88.5	65.0	78.14	843.50
May 16	June 8	24	....	....	90.0	68.0	79.09	866.25
OUT OF DOORS.								
May 5	June 6	33	August 27	82	91.0	43.0	75.31	1,066.1
May 6	June 8	34	August 15	68	93.0	43.0	76.04	1,123.2
May 7	June 9	34	August 19	71	93.0	43.0	76.69	1,145.5
May 8	June 8	32	August 14	67	93.0	43.0	77.16	1,093.0
May 11	June 10	31	August 7	58	93.0	60.5	77.93	1,082.8
May 13	June 8	27	August 24	77	93.0	60.5	77.87	941.6

Three lots of eggs, deposited May 13, 14, and 16, respectively, which were kept in the laboratory at a mean temperature of 77.8° F., hatched in 24 days, a total effective temperature of 834° F. being required for their incubation. Eggs which were deposited by ticks in tubes out of doors from May 5 to May 13 commenced to hatch in from 27 to 34 days. Rohr states that at a mean temperature of 30° C. (86° F.) eggs hatched in 19 to 23 days and at 35° C. (95° F.) in from 15 to 18 days. In this case the total effective temperature would be lowered somewhat. Lahille reports an instance in which eggs hatched in 20 days but does not give temperature records. He states that in one instance eggs deposited on April 30 passed the cold months and hatched September 6, or 129 days later.

The larva (Tables XLI–XLIV).—Our observations on the longevity of the larvæ are based upon the progeny of 6 ticks which dropped from a host on April 30, 1908, and which were at once placed in tubes on sand out of doors. The eggs from these ticks, which commenced depositing from May 5 to 13, were left with the ticks and commenced to hatch from June 6 to 10. The larvæ in the several tubes were all found to have died between August 7 and 24, or a maximum period of 82 days from the date the larvæ commenced to hatch. Thus it appears that at Dallas the progeny of ticks which dropped April 30 were all dead on August 24, or in a period of 116 days after the females dropped.

The larval molt occurs as soon as the sixth day after attachment, the last observed to molt having done so on the ninth day. Pound states that the molt takes place on the seventh day, Lahille reports it to occur from the seventh to the ninth day, while Rohr found 7 or 8 days to be required.

TABLE XLII.—*Nonparasitic period of Margaropus annulatus australis.*

Female dropped engorged.	Oviposition began.	Preoviposition period.	Hatching began.	Minimum incubation period.	All larvæ dead.		Larval longevity.
					Date.	Period from dropping of female.	
1908.	1908.	*Days.*	1908.	*Days.*	1908.	*Days.*	*Days.*
Apr. 30	May 5	5	June 6	32	Aug. 27	119	82
Apr. 30	May 6	6	June 8	33	Aug. 15	107	68
Apr. 30	May 7	7	June 9	33	Aug. 19	111	71
Apr. 30	May 8	8	June 8	31	Aug. 14	106	67
Apr. 30	May 11	11	June 10	30	Aug. 7	99	58
Apr. 30	May 13	13	June 8	25	Aug. 24	116	77

The nymph (Tables XLIII–XLIV).—The nymphs were found to molt as soon as the eighth day, or 14 days after attachment, the last observed molting on the thirteenth day, or 19 days after attachment. It was observed that in molting, as in *annulatus* proper, the young nymphs detach from the old point of attachment and reattach about one-eighth of an inch away, the old skins remaining attached to the hide after being shed.

Pound reports 7 days to be required for the nymphal stage, while Lahille places this period at 9 days.

The adult (Tables XLIII–XLIV).—In molting the females, like the nymphs, move from the old points of attachment, leaving the skins, and attach from one-sixteenth to one-eighth of an inch away. The mating habits of *australis* are similar to those of *annulatus* proper. After molting the male feeds for a number of hours and then starts in search of a mate with which, when found, it may remain until the female drops engorged. Males have been observed to remain in the position of copulation with females of *Margaropus annulatus* and *Dermacentor nitens* as long as 3 days. Lahille has observed copulation to take place off the host. We have not determined the period that the males remain upon the host, but Lounsbury states that it is usually about a month.

The adults have engorged and dropped as soon as the twenty-second day after attachment or 8 days after molting. In three infestations observed, the last engorged female dropped on the twenty-seventh day from attachment, or 9 days after the last nymph was observed to molt. Lounsbury reports the parasitic period (from the application of larvæ to the dropping of the females) to be from 18 to 38 days, but usually 23 days.

TABLE XLIII.—*The parasitic period of Margaropus annulatus australis.*

INFESTATION No. 1.

Date.	Remarks.
1908.	
Apr. 6, 4 p. m.	Larvæ placed on bovine.
Apr. 7 (1st day)	All attached.
Apr. 12 (6th day)	Several larvæ molting.
Apr. 13 (7th day)	A large percentage molted.
Apr. 14 (8th day)	All larvæ molted.
Apr. 21 (15th day)	Four nymphs molted (3 males, 1 female).
Apr. 22 (16th day)	A total of 20 molted.
Apr. 23 (17th day)	A total of 40 molted; one not molted.
Apr. 24 (18th day)	All have molted.
Apr. 25 (19th day)	Several mated.
Apr. 27 (21st day)	One female fully engorged but still attached.
Apr. 28 (22d day)	One female dropped engorged.
Apr. 29 (23d day)	Two females dropped. Seven fully engorged still attached.
Apr. 30 (24th day)	Fourteen females dropped engorged.
May 1 (25th day)	Four females dropped engorged.
May 3 (27th day)	The last female dropped engorged.

INFESTATION No. 2.

Date.	Remarks.
Aug. 11, 11 a. m.	Larvæ (hatched July 11) placed on bovine.
Aug. 12 (1st day)	All attached.
Aug. 17 (6th day)	Several molting.
Aug. 18 (7th day)	All but two or three have molted.
Aug. 19 (8th day)	All have molted.
Aug. 25 (14th day)	Two nymphs molted to males.
Aug. 26 (15th day)	Three more have molted.
Aug. 28 (17th day)	All have molted.
Aug. 29 (18th day)	All mated.
Sept. 1 (21st day)	Several females fully engorged
Sept. 2 (22d day)	Six females dropped engorged.
Aug. 4 (24th day)	Five females, the last, dropped engorged.

INFESTATION No. 3.

Date.	Remarks.
Aug. 20, 6 p. m.	Larvæ (hatched July 11) placed on bovine.
Aug. 21 (1st day)	All attached.
Aug. 26 (6th day)	Several molted.
Aug. 29 (9th day)	All have molted.
Sept. 5 (16th day)	Several nymphs molting.
Sept. 8 (19th day)	All the nymphs have molted.
Sept. 12 (23d day)	Four females fully engorged.
Sept. 13 (24th day)	Four females dropped engorged and several others are fully engorged.
Sept. 14 (25th day)	Eighteen fully engorged females were removed.
Sept. 17 (28th day)	One fully engorged female removed.
Sept. 18 (29th day)	One fully engorged female, the last, removed.

TABLE XLIV.—*Summary of parasitic periods of Margaropus annulatus australis.*

Infestation.	Larvæ.					Nymphs.				
	Attached.	First molted.		Last molted.		First molted.		Last molted.		Period following attachment.
		Date.	Period following attachment.	Date.	Period following attachment.	Date.	Parasitic period.	Date.	Parasitic period.	
	1908.	1908.	*Days.*	1908.	*Days.*	1908.	*Days.*	1908.	*Days.*	*Days.*
1	Apr. 6	Apr. 12	6	Apr. 14	8	Apr. 21	9	Apr. 24	12	15–18
2	Aug. 11	Aug. 17	6	Aug. 19	8	Aug. 25	8	Aug. 28	11	14–17
3	Aug. 20	Aug. 26	6	Aug. 29	9	Sept. 5	10	Sept. 8	13	16–19

TABLE XLIV.—*Summary of parasitic periods of Margaropus annulatus australis*—Continued.

Infestation.	Females dropped.				
	First.		Last.		Period following attachment.
	Date.	Parasitic period.	Date.	Parasitic period.	
	1908.	*Days.*	1908.	*Days.*	*Days.*
1	Apr. 28	7	May 3	12	22-27
2	Sept. 2	8	Sept. 4	10	22-24
3	Sept. 13	8	Sept. 18	13	24-29

LIFE CYCLE.

Under favorable conditions the progeny of a single tick may survive for a period of 82 days from the date hatching commences. The larvæ usually molt on the sixth day following attachment to the host, although in some instances as many as 9 days may be required. The nymphs usually molt in from 8 to 10 days later, but as many as 13 days have been observed to be required in some instances. Adults have been found to engorge in 7 days. In our observations the last females dropped engorged on the twenty-ninth day from attachment, but the period would probably be longer if males were not present. In one instance oviposition commenced on the day following dropping, but usually several days pass before such takes place. In June, at a mean temperature of 78° F., hatching began on the twenty-third day. An effective temperature of 834° F. appears to be required for incubation.

ECONOMIC IMPORTANCE.

This tick is so closely related to our species (*Margaropus annulatus*) that what has been said of *annulatus* proper regarding its importance as a pest may also apply to it. In the countries where it occurs *australis* is the same great pest that *annulatus* is in the southern United States, and transmits *Piroplasma bigeminum* in a similar manner. The habit of the larvæ in attaching to man, however, adds to its importance.

NATURAL CONTROL.

As with *annulatus,* birds (particularly blackbirds), mice, ants, toads, and lizards are probably its principal natural enemies. In Jamaica, the tinkling grackle (*Quiscalus crassirostris*), and the ani or "parrot-billed blackbird" (*Crotophaga ani*) are reported by Newstead (1909) to be its principal bird enemies.

ARTIFICIAL CONTROL.

The methods applicable in the control of *annulatus* proper apply in a general way to *australis*. Our observations indicate that the longevity of the larvæ may be somewhat shorter than that of *annulatus*. The long periods of warm weather in the Tropics should greatly assist in its eradication through starvation. If, however, the larvæ attach to small animals, as has been reported by Newstead (1909), and these develop to adults in any numbers, its eradication will be much more difficult.

Genus AMBLYOMMA Koch.

The five species of the genus Amblyomma which occur in the United States, namely, *americanum, cajennense, dissimile, maculatum,* and *tuberculatum,* have been studied and are considered in the following pages. The other species of this genus whose biology has been studied are *variegatum* by Barber (1894–95), in Antigua, *goldii* and *varium* by Rohr (1909), in Brazil, and *hebræum* (1899), *marmoreum,* and *variegatum* (1905), by Lounsbury, in South Africa. All five species which occur in this country and the three species studied in South Africa drop to pass the two molts. This also appears to be the case with the Brazilian species studied. Aside from the species which as adults attach to cold-blooded hosts only (*dissimile, goldii, marmoreum, tuberculatum*), the host relationship is not closely restricted. The species are able to withstand long periods of fasting while waiting for a host. While *americanum* is widely distributed, occurring in the Boreal and Austral regions, the other four species have only been found in the Tropical and Lower Austral Zones, three of these occurring only in the Gulf strip of the Austral Zone. The species are very hardy, yet require some protection, such as timber or underbrush; *maculatum,* however, exists on the prairie.

Only one species is known to transmit disease, namely, *hebræum,* which conveys the infection of heartwater of sheep, goats, and cattle in South Africa. Experiments to determine the possibility of *americanum* acting as a transmitter of splenetic fever of cattle have been conducted by two investigators. In both cases the results were negative.

THE GOPHER-TORTOISE TICK.

Amblyomma tuberculatum Marx.

The common name of the species is taken from the host of the adult.

DESCRIPTIVE.

Adult (Pl. IX, figs. 4–8).—Males from 7 by 4.5 mm. to 8 by 5 mm. Females, unengorged, 7 by 5 mm. to 10 by 6 mm.; engorged, 19 by 13.5 by 8 mm. to 24 by 18.5 by 11 mm. Males, scutum reddish

brown, with a somewhat complicated pattern, formed by rather broad metallic bands. Female reddish brown, scutum with a large silvery mark on each side, containing one or two dark spots, and two divaricate, silvery stripes extending forward from the hind margin and sometimes connected with the lateral spots.

Nymph (Pl. IX, figs. 2, 3).—Unengorged, 2.25 by 1.5 mm. to 4 by 2.5 mm.; engorged, 7 by 5 by 2.5 mm. to 10 by 6.5 by 4 mm.; capitulum 0.932 mm. long (from tip of palpi to base of emargination of scutum); scutum 1.2 mm. long by 1.6 mm. wide. Unengorged nymphs are reddish brown; the scutum has a large silvery spot on each side, united behind at the tips and in front much broken by the large punctures. Engorged nymphs are dark gray in color.

Larva (Pl. IX, fig. 1).—Unengorged, about 1.03 by 0.76 mm.; engorged, about 4 by 3 by 1.5 mm. The color unengorged is brownish yellow, intestines showing through darker; lateral margins of the scutum of a pinkish color. The color of the engorged larvæ varies considerably; partially engorged specimens are usually dull gray and those which are fully engorged or nearly so usually have a purple color. Larvæ that have been fully engorged for some time have a bluish brown color.

Egg.—Ellipsoidal, reddish brown, shining, smooth. Maximum for 10 eggs measured 0.893 by 0.647 mm.; minimum 0.847 by 0.647 mm.; average 0.864 by 0.655 mm.

HOST RELATIONSHIP.

The adults of this tick have been collected from the gopher tortoise only. Experimental attempts to attach them to bovines have failed. The nymphs are commonly found on the gopher tortoise and have been engorged in experiments upon a bovine. Engorged larvæ have been collected in large numbers from dogs and rabbits and in smaller numbers from cattle and two birds of prey, namely, the owl and the hawk. The fact that the bird hosts discovered have been birds of prey has suggested the thought that the larvæ crawled to the bird host from the small mammals devoured by them.

GEOGPAPHICAL DISTRIBUTION.

(Fig. 8.)

The type locality of this tick is Crescent City, Fla. The species appears to be commonly met with on the peninsula of Florida as far north as Hawthorn and it is reported as being rather common in southern Alabama. Neumann (1899) reports that there is a male in the Paris Museum which was collected in Cuba.

THE GOPHER-TORTOISE TICK, AMBLYOMMA TUBERCULATUM.

Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph. Fig. 3.—Engorged nymph. Fig. 4.—Engorged female, dorsal view. Fig. 5.—Females engorging on tortoise's feet. Fig. 6.—Male, dorsal view. Fig. 7.—Unengorged female, dorsal view. Fig. 8.—Engorged female, ventral view. (Original.)

LIFE HISTORY.

Observations on the biology of this tick have been published by Hooker (1909a).

The egg (Table XLV).—Three females were engorged upon a box tortoise. Their respective dimensions were: 24 by 18.5 by 11

FIG. 8.—The gopher-tortoise tick, *Amblyomma tuberculatum:* Distribution. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the tick. (Original.)

mm.; 19 by 13.5 by 10 mm. and 19 by 13.5 by 8 mm. The first female weighed 2.35 grams. This and the last female had a preoviposition period of 8 days at a mean temperature of 84° F. The second female began depositing on the tenth day after dropping.

The deposition period of the first and second females was 21 and 16 days respectively. The largest number of eggs deposited was 5,481; the average 3,839. Oviposition continued in one case for 21 days.

Many of the eggs deposited by these females were black and shriveled when deposited and ultimately only a very small percentage of them hatched. It is believed that in nature several thousand more eggs would be deposited, as the females observed by us were still of large size when deposition ceased. The first female recorded in the table died on the thirty-fourth day after dropping and the second female died on the twenty-eighth day. Although the engorged females are much larger than in *Amblyomma maculatum*, the number of eggs deposited is probably less, due to the much larger size of the eggs of *tuberculatum*. The process of oviposition is very similar to that of the South African species of Amblyomma as described and illustrated by Lewis (1892). The viscid membranes or papillæ are protruded from between the capitulum and the scutum to a far greater extent than in *Margaropus annulatus*, as observed by Cushman (see p. 73). This membrane is prolonged into two horns, or arms (see fig. 9), by means of which the fluid is directed to the eggs as deposited. At the writers' request, Mr. R. A. Cushman has made the accompanying drawing of this organ.

The incubation period appears to be longer than in the other species of Amblyomma observed, 91 days being the minimum period recorded. The average mean temperature during this period was 70.19° F. and the total effective temperature 2,474° F. Under natural conditions this period may be somewhat shorter. The records given in the accompanying table were all made upon eggs kept in the laboratory on moist sand. Only a very small percentage of those deposited hatched, many of them being shriveled and black when deposited.

TABLE XLV.—*Incubation and larval longevity of Amblyomma tuberculatum.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
					Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	*Days.*		*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
Aug. 27	Dec. 4	100	Dec. 22, 1908	18	97.5	34.0	70.26	2,726
Aug. 29	Nov. 27	91	Mar. 2-17, 1909	95-110	97.5	34.0	70.19	2,474
Aug. 31	Dec. 4	96	Dec. 22, 1908	18	97.5	34.0	69.63	2,557
Sept. 1	Dec. 4	95	Mar. 3-20, 1909	94-106	97.5	34.0	69.47	2,515
Sept. 7	Dec. 4-29	114—	Jan. 13, 1909	15+				

The larva (Table XLV).—The greatest larval longevity observed by us was between 95 and 110 days. None of the lots, the longevity of which is recorded in Table XLV, contained more than 200 specimens and the three lots which had a longevity of from 15 to 18 days

each contained only one or two larvæ. Three slightly engorged larvæ collected from a rabbit on December 21, 1907, were placed upon a bovine on March 10; two were found attached the following day, while the third was found dead on March 12. While the two ticks remained attached for only a few days, the fact that they reattached shows the possession of considerable vitality. A few specimens of a lot of larvæ from one-fourth to three-fourths engorged when collected November 30, 1908, lived for three months.

Engorged larvæ taken from a rabbit on December 21, 1907, and kept in the laboratory at a mean temperature of 61.4° F., did not commence to molt until 86 days later, having required a total effective temperature of 1,583° F. Engorged larvæ collected in November began to molt in from 107 to 147 days.

On the dog no particular preference as to position of attachment was observed, but on the rabbit the larvæ were found in great patches near the base of the ears, a few being in and on the ears. Larvæ have been taken in abundance on dogs and rabbits and a few specimens on cattle and sparrowhawks.

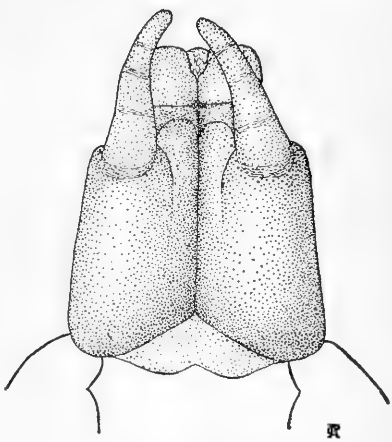


FIG. 9.—The gopher-tortoise tick: *Vesica biloba* extended between the scutum and capitulum in position to receive an egg from the ovipositor. Greatly enlarged. (Original.)

The nymph (Tables XLVI, XLVII).—On June 8, 1909, one nymph was alive in a tube which contained 8 specimens that molted from larvæ between March 15 and March 30, 1909. This individual had lived between 70 and 80 days up to the time it was put on a host (June 8). One nymph which molted March 11, 1909, was alive and able to attach to a host when applied on May 31, 1909, a period of 81 days after molting. Other lots which molted in March, 1909, and were kept on sand died in from 27 to 56 days. It should be stated that all of these nymphs were collected as larvæ late in the fall of 1908 and did not molt until March. Probably specimens dropping during warm weather so that they would molt to nymphs in a short time would live for a much longer period.

Nymphs were found to attach readily to a bovine, but some trouble was experienced on account of scabs forming around the mouthparts and causing the ticks to drop before becoming fully engorged. Specimens were found to change their point of attachment several times before imbibing much blood. The shortest period in which engorgement took place upon a bovine was 8 days, the greater number dropping on the ninth and tenth days, the last to leave the

host dropping on the eleventh day. Upon a cold-blooded host the period of engorgement will undoubtedly be found to be much longer, as was found to be the case with *Ambylomma dissimile.* Attempts to get nymphs to attach to a horned toad were unsuccessful.

TABLE XLVI.—*Engorgement of nymphs of Amblyomma tuberculatum.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.											Total number dropped.
		1	2	3	4	5	6	7	8	9	10	11	
Apr. 14, 1908	Bovine	0	0	0	0	0	0	0	0	0	5	2	7
Apr. 15, 1908	do	0	0	0	0	0	0	0	1	2	3	2	8
May 20, 1908	do	0	0	0	0	0	0	0	1	4	3	2	10
May 7, 1909	do	0	0	0	0	0	0	0	1	0	0	0	1
May 11, 1909	do	0	0	0	0	0	0	0	0	0	1	2	3

At a mean temperature of 81° F. nymphs which dropped the last of May commenced to molt in 29 days, a total effective temperature of 1,104° F. having been required. The molting period of nymphs which become males and females is about the same. It was found that when the engorged nymphs were placed in tubes on moist sand they at once burrowed into it out of sight. When examined they were found an inch or more beneath the surface, in which position molting took place. This habit was not observed in engorged larvæ, but is probably the same. Although observations on this habit have not been made in other species of ticks, owing largely to the fact that it was necessary to keep them on an impenetrable surface in order that the exact dates of molting could be observed, it seems quite probable that some of them may do so also. Such a habit is of great advantage to the tick in protecting it from enemies during the quiescent period, as well as in preventing drying out.

TABLE XLVII.—*Molting of engorged nymphs of Amblyomma tuberculatum engorged on bovine.*

Date engorged nymphs dropped.	Number.	Engorged nymphs molted—days following dropping.															Number molted.			Temperature from dropping to date first tick molted.		
		29	32	36	37	38	39	44	46	48	49	51	53	66	203	207	Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
																				°F	°F	°F
Apr. 23, 1908	1	0	0	0	0	0	0	0	0	0	0	0	0	1♂	0	0	1	0	1	91.5	47	76.29
Apr. 24, 1908	6	0	0	0	0	0	0	0	0	0	1♂ 3♀	... 1♀	1♂	0	0	0	2	4	6	89	47	74.72
Apr. 25, 1908	5	0	0	0	0	0	0	0	1♂	2♀	0	1♀	0	0	0	0	1	3	4	89	47	74.73
Apr. 26, 1908	2	0	0	0	0	0	0	0	0	0	1♀	0	0	0	0	0	0	1	1	91.5	47	75.11
May 28, 1908	1	0	0	0	1♂	0	0	0	0	0	0	0	0	0	0	0	1	0	1	91.5	69	80.50
May 29, 1908	4	0	0	1♀	0	1♂	1♀	1♀	0	0	0	0	0	0	0	0	1	3	4	91.5	69	80.61
May 30, 1908	3	1♂	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	91.5	69	81.05
May 31, 1908	2	0	0	1♂	1♀	0	0	0	0	0	0	0	0	0	0	0	1	1	2	91.5	69	81
Nov. 24, 1908	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♀	0	1	1	100	17	67.15
Dec. 2, 1908	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1♂	0	1	0	1	100	17	67.89
May 21, 1909	1	1♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	100	47	86.17
May 22, 1909	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	...	...	1	100	47	86.56
Total	28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	14	24			

The adult.—Among the individuals observed to molt to the adult stage there was a predominance of females. The greatest adult longevity observed was about 90 days; other specimens lived from 17 to 76 days. All of these records were made during midsummer. A few ticks of both sexes remained active, when kept in tubes in the laboratory, for more than 2 months during the summer before being placed upon a host. It is certain that with abundant material, placed under natural conditions, adults would be found to live much longer than those observed by us.

Several males and 3 females placed upon a tortoise on July 29, 1908, readily attached. The first female to engorge dropped 20 days later, measuring 24 by 18.5 by 11 mm. Next to *Amblyomma varium*, which has been recorded by Rohr (1909, p. 120) as measuring 28 by 24 by 15 mm., this is the largest tick on record. The second female dropped engorged on the twenty-first day after attachment and measured 19 by 13.5 by 10 mm. The third female dropped on the twenty-fifth day after attachment and measured 19 by 13.5 by 8 mm. During the period of attachment none of these females was observed in copulation. Upon removing the first female from the bag in which the tortoise had been placed it was found apparently in copulation with a male which had also dropped from the host. This fact suggests the possibility that copulation takes place after the female drops engorged.

Males have been observed to remain attached for a long time after the females drop, and this habit accounts for their being more commonly met with upon tortoises. One of the three males which attached to a tortoise July 29, 1908, remained on the host 43 days after the last female dropped and the other was still attached but dead when the tortoise died on January 5, 1909, thus having been attached 135 days after the last female dropped, or a total period of 160 days. The males attached to the margin of the shell as well as to the body of the tortoise. It is conceivable that the females may also thus attach to the shell, but if this actually occurs the period of engorgement must be greatly prolonged owing to the poor blood supply. Attempts to secure the attachment of adults to horned toads (*Phrynosoma cornutum*) were unsuccessful.

LIFE CYCLE.

Larvæ may live for at least 95 days during the winter months. The period required for engorgement has not been determined. At winter temperature in the laboratory at Dallas 86 days passed before molting commenced. During this period a total effective temperature of 1,583° F. was accumulated. The longest molting period recorded was 165 days. The greatest nymphal longevity

recorded was 81 days. At the end of this period one specimen was still able to attach to the host. On a warm-blooded host the nymphs may engorge in 8 days and molting may commence as soon as 29 days after dropping. A total effective temperature of 1,104° F. appears to be required to produce this molt. Adults may live for 90 days and engorge as soon as 20 days after application to a host. Oviposition may commence as soon as the eighth day after dropping and as many as 5,481 eggs may be deposited. The minimum incubation period recorded (in winter) was 92 days. During this period a total effective temperature of 2,474° F. was accumulated.

ECONOMIC IMPORTANCE.

While this tick has not been considered of economic importance, the fact that it occurs on cattle and in large numbers on dogs and certain small mammals suggests the possibility of its becoming so.

NATURAL CONTROL.

No particular enemies of this tick have been observed. However, in experiments several ticks were lost by being devoured by the tortoise.

THE IGUANA TICK.

Amblyomma dissimile Koch.

The common name of this species is given it because the iguana was the first animal upon which we collected it as well as being one of its most common hosts. Newstead (1909, p. 445) has made use of the name "bullfrog tick."

DESCRIPTIVE.

Adult (Pl. X, figs. 3–5).—Males from 4 by 2.75 mm. to 5.25 by 3.33 mm. Females, unengorged, from 4 by 2.5 mm. to 5.5 by 3.75 mm.; engorged, from 14 by 9 by 5 mm. to 17 by 10 by 6 mm. Newstead has described the coloration of the engorged female as ochreous to yellowish gray; scutum chocolate brown with dull coppery markings, forming a distinct spot at the apex.

Nymph (Pl. X, fig. 2).—Unengorged, about 2 by 1.1 mm.; color varying from light to a darker brown. Length of capitulum 0.497 mm. (from tip of palpi to base of emargination of scutum); scutum 0.737 mm. long by 0.983 mm. wide. Engorged, from 4.5 by 3 by 2 mm. to 5 by 3.25 by 2 mm. The color varies according to whether blood or lymph has been engorged, the lymph giving a light gray, and the blood a brownish yellow color.

Larva (Pl. X, fig. 1).—Unengorged, from 0.867 by 0.578 mm. to 0.961 by 0.617 mm.; engorged, 2 by 1.15 mm. Capitulum 0.236 mm. long (from tip of palpi to base of emargination of scutum); scutum

0.9 mm. long by 0.6 mm. wide. The color varies as does that of the nymphs, a somewhat higher percentage of this species than others having a light gray color. A few have a pink color when they drop.

Egg.—Ellipsoidal, light brown, shining, smooth. The maximum size for 10 was 0.677 by 0.570 mm., the minimum 0.631 by 0.539 mm., with an average of 0.652 by 0.560 mm.

HOST RELATIONSHIP.

The type host is not known. This tick attaches to cold-blooded animals, particularly iguanas and toads, upon both of which it engorged at Dallas. The toad, however, died before the larvæ all engorged, due to being confined in a cage. In rearing experiments the larvæ and nymphs readily attached to and engorged upon a bovine, but the adults would attach to cold-blooded hosts only. It thus seems probable that in nature the immature stages attach to both cold and warm blooded animals and that the adults attach only to the former class. Newstead states that in Jamaica it is apparently confined to the common toad or so-called "bullfrog" of the island (*Bufo marinus*).

GEOGRAPHICAL DISTRIBUTION.

The type locality is Mexico. During 1907 nymphs and adults of this species were collected by one of the authors (Wood) from iguanas which had been brought to Brownsville, Tex., from the Isthmus of Tehuantepec. The species has been recorded from Mexico, Guatemala, Honduras, Nicaragua, Panama, Jamaica, Antigua, Barbados, Trinidad, Colombia, Venezuela, Guiana, Brazil, Paraguay, Argentina, and the Philippine Islands.

LIFE HISTORY.

The only information upon the biology of this tick that the authors have found is furnished by Newstead (1909). This author is in error in supposing that the molts are passed upon the host, as such is not the case.

Egg (Tables XLVIII, XLIX).—In the laboratory in June and July at a mean temperature of 82° to 86° F. oviposition commenced on the sixth day after dropping and continued for 16 and 17 days. The larger number of eggs deposited by the two females from which counts were made was 1,655. Newstead (1909, p. 446), however, records 1,784 from one female, deposition commencing on the seventh day and continuing for 17 days. The minimum incubation period recorded by us was 27 days. This record was made on eggs deposited early in August. The mean temperature during incubation was 85° F. An effective temperature of 1,133° F. appears to be required for the incubation of the eggs. The first tick, the oviposition of which

is recorded in the following table, was about three-fourths engorged, having been collected on an iguana. The second female was engorged on a box turtle and measured 14 by 9 by 5 mm. It died on the twenty-fifth day after dropping.

TABLE XLVIII.—*Oviposition of Amblyomma dissimile.*

Date engorged female dropped.	Number of eggs deposited—days following dropping.																	Total number of eggs.
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
June 2, 1908	235	342	208	275	134	158	70	25	21	36	26	16	10	5	0	10	2	1,573
July 30, 1908	186	318	317	283	132	142	95	64	38	32	18	7	12	5	2	4	0	1,655
Average																		1,614

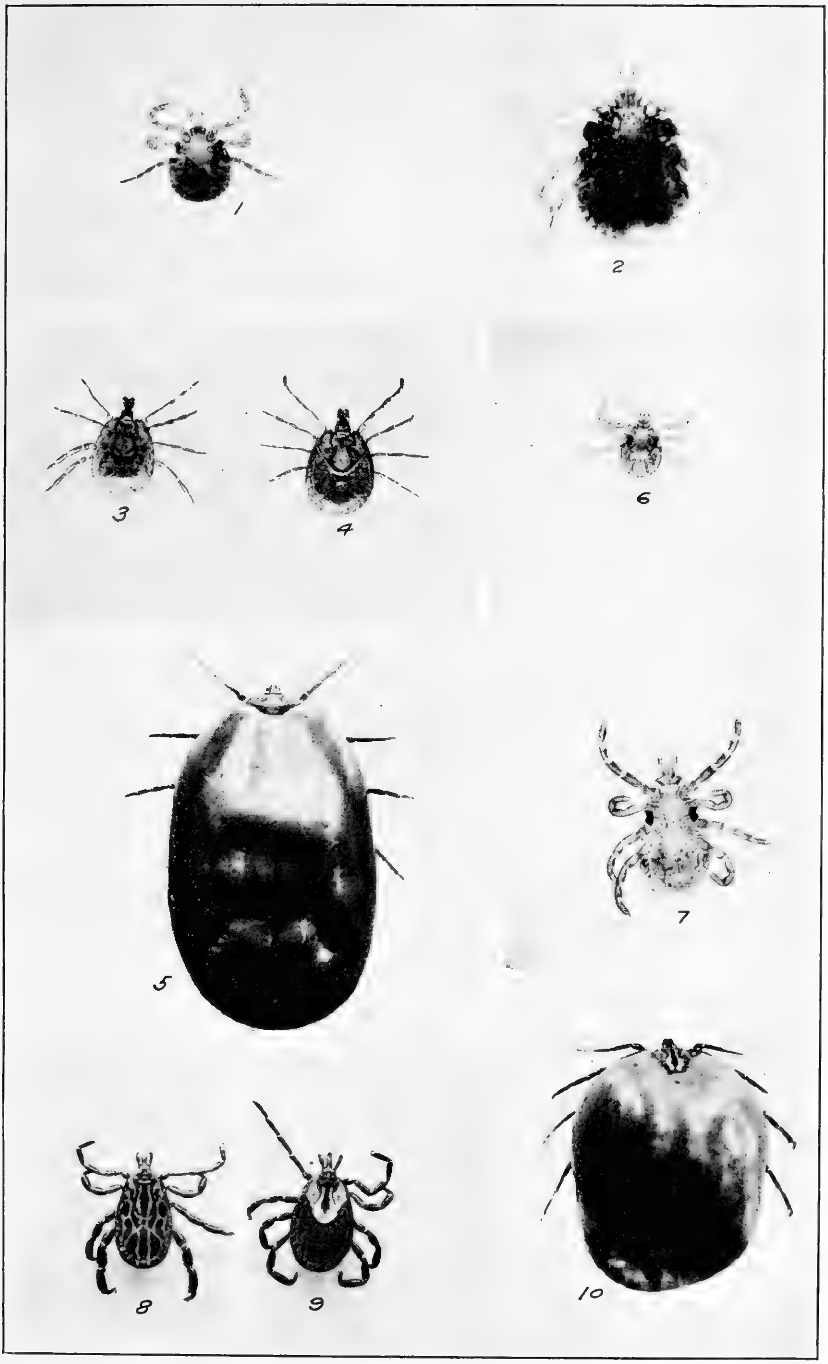
TABLE XLIX.—*Incubation and larval longevity of Amblyomma dissimile.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
					Maximum.	Minimum.	Average daily mean.	Total effective.
1908		Days.	1908	Days.	°F.	°F.	°F.	°F.
May 5	June 13	40			91.5	56	76.93	1,357.5
May 18	June 21	35			91.5	68	80.57	1,283.5
June 9	July 14	36	Oct. 17	95	93.5	69	81.00	1,368
June 13, 14	July 15	33	Before Oct. 7	84	93.5	70.5	81.46	1,269
June 17	July 20	34	Oct. 2	74	90	70.5	82.01	1,326
Aug. 5, 6	Aug. 31	27	Nov. 13-26	74-87	99	73	85.17	1,138.5
Aug. 7, 8	Sept. 2	27	Nov. 13-26	72-85	99	73	84.96	1,133.
Aug. 8, 9	Sept. 5	29	Nov. 26-Dec. 9	82-95	96.5	73	84.53	1,204.5
Aug. 11-14	Sept. 7	28	Nov. 16	70	98.5	75	84.87	1,172

Larva (Tables XLIX-LI).—The longevity of larvæ which hatched on July 14, 1908, was 95 days. This was the greatest longevity observed by us. Engorgement took place on a bovine as soon as 4 days, the greatest number dropping from the fifth to seventh days. On a cold-blooded host (a tortoise) 10 days were required for engorgement. Ticks placed upon a bovine had all dropped on the ninth day, whereas upon a tortoise the last dropped upon the sixteenth day. An important point is here brought out in the fact that upon cold-blooded animals a much longer period is required for engorgement.

TABLE L.—*Engorgement of larvæ of Amblyomma dissimile.*

Date larvæ applied.	Host.	Larvae dropped engorged—days following application.												Total number dropped.
		4	5	6	7	8	9	10	11	12	14	15	16	
1908.														
July 2	Bovine	12	29	40	28	8	3	0	0	0	0	0	0	120
July 23	Tortoise	0	0	0	0	0	0	6	3	12	16	3	3	43
Aug. 11	Bovine	1	8	4	3	0	0	0	0	0	0	0	0	16



THE IGUANA TICK, AMBLYOMMA DISSIMILE, AND THE GULF COAST TICK, AMBLYOMMA MACULATUM.

Amblyomma dissimile: Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph (balsam mount). Fig. 3.—Male, dorsal view. Fig. 4.—Unengorged female, dorsal view. Fig. 5.—Fully engorged female (alive). *Amblyomma maculatum:* Fig. 6.—Unengorged larva. Fig. 7.—Unengorged nymph (balsam mount). Fig. 8.—Male, dorsal view. Fig. 9.—Unengorged female, dorsal view. Fig. 10.—Engorged female, dorsal view. (Original.)

At a mean temperature of 86.5° F. larvæ which engorged upon a tortoise molted as soon as the seventh day after dropping. However, the greatest number molted on the eleventh day. At a mean temperature of about 83.5° F. larvæ engorged upon bovines required a minimum of 10 days from dropping to molting, the greatest number molting on the twelfth day. Thus it appears that larvæ engorged on warm-blooded and cold-blooded animals have approximately the same molting period. A total effective temperature of at least 305° F. appears to be required for the molting of larvæ.

TABLE LI.—*Molting of engorged larvæ of Amblyomma dissimile.*

Date engorged larvæ dropped.	Host.	Number.	Engorged larvæ molted—days following dropping.									Total number molted.	Temperature from dropping to date first tick molted.		
			7	9	10	11	12	13	14	15	16		Max.	Min.	Av. daily Mean.
1908.													°F.	°F.	°F.
July 6	Bovine	11	0	0	0	2	5	1	2	0	0	10	94	74	83.29
July 7	...do	24	0	0	1	5	13	2	1	0	0	22	94	74	83.45
July 8	...do	35	0	0	0	8	9	7	2	0	0	26	94	74	83.71
July 9	...do	23	0	0	0	0	0	2	0	0	0	2[1]	95	74	84.09
Aug. 2	Tortoise	6	0	0	0	4	2	0	0	0	0	6	99	73	86.37
Aug. 3	Toad	8	0	0	0	0	0	7	0	0	0	7	99	73	86.51
Do	Tortoise	3	0	0	0	3	0	0	0	0	0	3	99	73	86.41
Aug. 4	...do	12	0	2	5	3	1	0	0	0	0	11	99	73	86.14
Aug. 6	...do	17	1	0	2	12	2	0	0	0	0	17	99	73	86.59
Aug. 7	...do	2	0	0	0	1	1	0	0	0	0	2	99	73	86.94
Aug. 8	...do	3	0	0	1	2	0	0	0	0	0	3	96	73	86.30
Aug. 15	Bovine	1	0	0	0	0	0	0	1	0	0	1[1]	96	75	84.32
Aug. 16	...do	8	0	0	0	0	0	0	1	1	0	2[1]	96	75.5	84.17
Aug. 17	...do	3	0	0	0	0	0	0	1	2	0	3	96	75.5	83.90
Aug. 18	...do	3	0	0	0	0	0	0	0	1	1	2[1]	93	75.5	83.61
	Total	159										107[1]			

[1] Some specimens in this lot were destroyed before they molted.

The nymph (Table LII).—In order to determine the longevity of nymphs, five lots, each containing several specimens, were kept in tubes on moist sand in the laboratory. The longevity of these lots varied from 86 to 130 days. Those which molted July 20, 1907, were all dead by October 26, 1907, or 95 days after molting. One among those which molted August 13–15, 1907, lived between 124 and 130 days; one of the lot which molted August 15–16, 1907, lived between 104 and 111 days, and one of those which molted August 29 to September 3, lived between 108 and 122 days.

The shortest period in which they engorged on a bovine was 5 days, the greatest number dropping on the sixth day. In August, 11 days were required for engorgement upon a tortoise, the greatest number requiring 13 days. It appears from these two tests that nymphal engorgement is much more rapid on warm-blooded than on cold-blooded animals.

TABLE LII.—*Engorgement of nymphs of Amblyomma dissimile.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.									Total number dropped.
		5	6	7	8	9	11	12	13	14	
1908.											
Aug. 1	Bovine....	1	6	1	2	0	0	0	0	0	10
Aug. 8	Tortoise...	0	0	0	0	0	1	1	4	2	8

The molting of 28 individuals was observed. In August, at a mean temperature of 83° F., molting commenced in 12 days, the greatest number molting from the fifteenth to seventeenth days. An effective temperature of at least 479° F. appears to be required. There is no marked difference in the periods required for the molting of nymphs engorged on warm-blooded and on cold-blooded hosts.

The adults.—Seventy-one per cent of the 28 individuals which molted to adults were females. On June 2, 1908, 4 males and 5 females which were slightly engorged were collected on an iguana. The last female of this lot died between July 18 and August, 1908, while one of the males lived until October 9, 1908, a period of 129 days. In a lot consisting of 1 male and 2 females which molted September 5, 1908, the male showed the greatest longevity, living 103 days, although it was very weak for over a month prior to its death. A female which molted September 13, 1908, lived about three months in a pill box under very unfavorable conditions.

Numerous attempts were made to get males and females to attach to a bovine, but all failed, and it is probable that as adults they never attach to warm-blooded hosts. On July 2, 5 females and 1 male were placed upon a box tortoise and all readily attached. On the second day following, 2 females had detached and were missing, apparently having been eaten by the tortoise, and on the following day a third female was also missing. The male and remaining female which were attached at the anterior part of the body of the tortoise remained attached until July 26, when the male was found to have reattached at the anterior part of the host's body. On July 27 the female commenced engorging and the following day the male was missing. On July 30, 28 days after attachment, the female had become fully engorged and was removed in order that it might not be injured or lost in dropping. This tick measured 14 by 9 by 5 mm. During attachment no signs of mating were observed; however, as eggs deposited by the female hatched, it is probable that the tick was fertilized just prior to the date that it commenced to increase noticeably in size. It thus appears that mating continues for only a very short time. The position at which the female attached and engorged was just

beneath the carapace midway between the head and the left fore leg. Newstead reports 3 females to have engorged on a toad in 14, 17, and 23 days, respectively.

LIFE CYCLE.

Larvæ may live 95 days in summer and fall; they engorge as soon as 4 days and in summer may molt as soon as 7 days, at least 305° F. of effective temperature being required. Nymphs may live as long as 130 days during summer and fall; they engorge as soon as 5 days after attaching to a host, and may molt in 12 days after dropping, 479° F. of effective temperature being required. Among the individuals which we have observed to molt from nymphs, there was a predominance of females. Adults may live 129 days; they may engorge in 14 days, commence ovipositing 6 days later, and deposit as many as 1,784 eggs. In summer eggs may hatch in 27 days, 1,133° F. of effective temperature being required. The longevity of all stages of this tick appears to be shorter than any of the Amblyommas studied by us with the possible exception of *A. tuberculatum*.

ECONOMIC IMPORTANCE.

So far as is now known this tick is of no economic importance. However, a better knowledge of the host relations of the species may show it to be of some importance.

NATURAL CONTROL.

No natural enemies of this tick have been found by us.

THE GULF COAST TICK.

Amblyomma maculatum Koch.

DESCRIPTIVE.

The common name of this species is given because of the prevalence of the tick along the Gulf coast.

Adult (Pl. X, figs. 8–10).—Males from 4 by 2.25 mm. to 6 by 3 mm. Females, unengorged, 4 by 2.25 mm. to 5 by 2.33 mm.; engorged, from 14 by 10 by 7 mm. to 18 by 13 by 8 mm. Males dark brown, scutum brown, lineate with silvery white, lines more or less connected. Unengorged females dark brown, scutum silvery white behind, brown in front, with one median and two lateral interrupted stripes. Engorged females leaden gray.

Nymph (Pl. X, fig. 7).—Unengorged, about 1.33 by 0.75 mm.; engorged, about 4.5 by 3 by 2 mm. Dark bluish gray, shining; some of the engorged nymphs are dull white, due to the ingestion of lymph. Capitulum 0.392 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.617 mm. long by 0.598 mm. wide.

Larva (Pl. X, fig. 6).—Unengorged, 0.617 by 0.402 mm. to 0.631 by 0.416 mm.; engorged, 1.5 to 1.66 mm. long by 1 mm. wide.

Color brown, lateral margins of scutum with a dark red marking. Some engorged specimens are pink colored at the time of dropping; a few are dull white, but the greatest number are dark gray. Capitulum 0.136 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.23 mm. long by 0.33 mm. wide.

Egg.—Ellipsoidal, brownish yellow, smooth, shining. The maximum size of 10 eggs measured was 0.539 by 0.385 mm., minimum size 0.508 by 0.400 mm., and average size 0.520 by 0.397 mm.

HOST RELATIONSHIP.

The type host is not known. Records of 49 collections have been made in Texas and Louisiana by agents of the bureau. Of these, 12 were on dog, 11 on cattle, 8 on horse, 7 on meadowlark, 3 on sheep, 2 on goats, 1 on man, 1 on wolf, 1 on fox, 1 on quail, 1 on red-winged blackbird, and 1 on jack rabbit. A deer and a beetle have also been recorded as hosts. The larvæ of this species have not been collected by us on hosts in nature. Birds probably act as hosts for the larvæ and are undoubtedly common hosts of the nymph. Of the above-mentioned collections, the seven lots of this species on meadowlarks and the last four lots listed were all nymphs. Cattle and dogs appear to be the most common hosts of the adults, although, as is indicated by the host list given above, the species has no decided host limitations.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 10.)

The type locality is "Carolina." The species occurs commonly along the Gulf Coast from Cameron Parish, La., to the Rio Grande in Texas. It has been taken inland as far as Columbus, Victoria, and Laredo, Tex. A single male was collected on a dairy cow at Dallas, Tex. No cattle had recently been brought to this dairy from other points. Five lots have been collected by agents of the bureau on dogs at Orlando, Fla. The Marx collection contains a male specimen (labeled by Marx) from Tulare County, Cal. The Marx collection also contains a male and an unengorged female, labeled Memphis, Tenn. It seems quite probable that in these two latter instances the ticks were carried on cattle which were shipped inland. Prof. H. A. Morgan has called attention to the fact that the ticks collected by Niles (1898, pp. 28, 29) in Virginia and referred to as *Dermacentor occidentalis* belong to this species.

Outside of this country this tick is known to occur in Mexico, Jamaica, Ecuador, Peru, Brazil, Paraguay, Chile, and Argentina.

LIFE HISTORY.

Observations on the biology of this species have been made by Lahille (1905), Hunter and Hooker (1907), Hooker (1908), and Newstead (1909).

FIG. 10.—The Gulf Coast tick, *Amblyomma maculatum:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the species. (Original.)

The egg (Table LIII).—In May and September at a mean temperature of 74° F. oviposition commenced as soon as the third day after dropping. The largest number of eggs deposited by any one of the seven females observed was 11,265, the smallest number

4,560, with an average of 8,282. The female which deposited the maximum number of eggs measured 17 by 12 by 6 mm. This female began depositing on the third day after dropping (September 1, 1907), and deposition was completed in 16 days, 1,793 eggs having been deposited on one day. The individual which deposited the smallest number of eggs was the largest tick observed by us, measuring 18 by 3 by 8 mm. The cool weather which followed the dropping of this tick caused an interrupted and prolonged period of deposition and a considerable reduction in the total number of eggs deposited. Four females, engorged on a bovine, measured 14 by 10 by 7 mm., 18 by 11.5 by 8 mm., 15 by 10.5 by 7 mm., and 18 by 12 by 7 mm., respectively. Others were engorged on a horse and on a sheep. The preoviposition period varied from 3 to 9 days and the deposition period from 13 to 75 days.

The minimum incubation period in May at a mean temperature of 81° was 21 days. An effective temperature of 793° F. appears to be required for embryonic development.

TABLE LIII.—*Incubation and larval longevity of Amblyomma maculatum.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
					Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	*Days.*	1908.	*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
May 20	June 10	22	Sept. 24	107	90	68	79.5	803.25
May 21	June 11	22	...do......	107	90	68	79.2	797.25
May 30	June 19	21	...do......	98	91.5	69	81	793.75
	1909.		1909.					
Nov. 25	Mar. 6	102	June 6	92	87	17	59.22	1,654.00
1909.								
Oct. 8	Nov. 28	52	Mar. 17	116	94	41	70.05	1,406.50
AT OUTDOOR TEMPERATURE.								
1906.	1906.		1907.					
Sept. 5	Oct. 6	....	Feb. 18	136	....	....	....	....
Sept. 7	...do....	....	Apr. 1	179	....	....	....	....
Sept. 9	...do.....	28	Jan. 23	110	95	42	77.4	963.20
			1906.					
Sept. 11	Oct. 7	27	Dec. 8	63	95	42	76.68	909.36
1908.	1908.		1909.					
Aug. 23	Sept. 16	24	Mar. 3	168	100	59	83.4	969.60
	1909.							
Oct. 3	Feb. 20	141	June 8	108	89	10	60.98	1,201.65
Oct. 2	...do....	142	June 17	117	89	10	61.01	1,224.25

The larva (Tables LIII–LIV).—The longevity of larvæ hatched October 6, 1906, was 179 days, which was the maximum period observed by us. This lot of ticks was kept out of doors.

The shortest period in which larvæ engorged was 3 days, over 92 per cent of them dropping on the fourth and fifth days following attachment.

TABLE LIV.—*Engorgement of larvæ of Amblyomma maculatum.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
1906.												
Oct. 9	Dog	0	0	0	0	1	0	0	0	0	0	1
1907.												
Sept. 23	Bovine	0	0	1	65	23	9	1	0	0	0	99
Oct. 29	...do	0	0	0	(1)	29	7	3	0	0	0	39
1908.												
Mar. 27	...do	0	0	1	115	51	0	0	0	0	0	167
July 18	...do	0	0	0	3	14	2	0	0	0	0	19
July 24	...do	0	0	0	1	13	1	1	0	0	0	16
Aug. 18	...do	0	0	0	0	2	0	0	0	0	0	2

[1] Larvae which molted on this day were included with those which molted on the following day.

At a mean temperature of 85.7° F. molting began as soon as 7 days. One of 7 larvæ which dropped November 4, 1908, molted 121 days later. The mean temperature during this period was about 60.8° F. An effective temperature of at least 299° F. is required for molting.

The nymph (Table LV).—There are no records at hand on the longevity of the free nymph.

Engorgement took place as soon as 5 days, 75 per cent dropping on the sixth and seventh days after attachment. The longest engorgement period observed was 11 days. The tick upon which this record was made was collected on a meadowlark and placed upon a rabbit about a month later, when it readily attached.

TABLE LV.—*Engorgement of nymphs of Amblyomma maculatum.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.											Total number dropped.
		1	2	3	4	5	6	7	8	9	10	11	
Oct. 27, 1907	Dog	0	0	0	0	0	0	2	0	0	0	0	2
Oct. 29, 1907	Bovine	0	0	0	0	3	8	5	1	0	0	0	17
Nov. 1, 1907	Dog	0	0	0	0	1	0	0	0	0	0	0	1
Aug. 11, 1908	Bovine	0	0	0	0	0	3	0	0	0	0	0	3
Mar. 27, 1909	Rabbit	0	0	0	0	0	0	0	0	0	0	1	1

The shortest molting period recorded for nymphs is 17 days. This record is based upon specimens which dropped August 17, 1908. The mean temperature was 84° F. and the total effective temperature 694° F. during the period. There was considerable variation in the molting periods of ticks dropped in November which were kept under nearly the same conditions, the shortest period being 51 days and the longest 71 days.

The adult (Tables LVI, LVII).—Two-thirds of the 24 adults, the molting of which was observed by us, were females. The greatest

adult longevity recorded was between 388 and 411 days. These ticks were kept on moist sand in the laboratory. The longevity of the sexes appears to be about the same.

TABLE LVI.—*Longevity of adults of Amblyomma maculatum.*

Molted.				Date last tick died.	Longevity in days.
Date.	Male.	Female.	Total.		
1907.				1908.	
December	2	2	4	Dec. 6	365±
Dec. 30	1	1	2	Jan. 22–Feb. 14	388–411
1909.				1910.	
May 3	1	0	1	Nov. 28	209
May 4–5	1	1	2	Sept. 26–Oct. 18	144–167
May 5	0	1	1	Sept. 26	144

Males and females that had been reared from nymphs when placed upon the host attached quite readily. Twelve days passed, however, before they were found in copulation. After a male mates with a female it usually remains with her until she drops; it then goes in search of another mate. Mr. J. D. Mitchell states that he has observed the sexes in copulation after having been removed from the host.

Engorgement has been found to take place as soon as 14 days. Partially engorged females reattach if they have not been injured in being removed. The largest specimen which we have observed was collected partially engorged from a sheep; it reattached and engorged upon a bovine. This specimen remained attached for a day and a half after being apparently fully engorged. Upon removal it was found to weigh 1 gram and to measure 18 by 13 by 8 mm. Next to *Amblyomma tuberculatum* this is the largest species that occurs in the United States.

TABLE LVII.—*Engorgement of females of Amblyomma maculatum.*

Adults applied.	Host.	Females dropped engorged.	Period of attachment.	Size engorged.
1908.		1908.	*Days.*	
Apr. 27	Bovine	May 11	14	14 by 10 by 7 mm.
Do	...do	May 12	15	18 by 11.5 by 8 mm.
Apr. 27 (2)	...do	May 14 (2)	17	15 by 10.5 by 7 mm.
Apr. 27	...do	May 15	18	18 by 12 by 7 mm.

Males remain attached for long periods after the females drop and may mate with several females. This habit of remaining upon the host after the females have dropped accounts for so many males being taken at certain seasons of the year when females can not be found. On August 28, 1907, Mr. J. D. Mitchell of this bureau examined the ears of 340 cattle at a branding chute in Goliad County, Tex., and found 4 females and about 100 males, none of these being in coitu. The males were frequently in clusters, as many as 9 being counted in

one cluster, 5 or 6 being a frequent number. The following day Mr. Mitchell examined the ears of 933 cattle in Refugio County, Tex., and found 15 females and several hundred males. In two instances specimens were found in coitu. Many of the males were in clusters of from 5 to 10. In another locality 567 cows were examined, 1 female tick and 3 males being found, all on different animals. Our records show that males were removed from hosts a month after all the females had dropped, and it is probable that they remain on the host for a number of months. As with some other species, the males, having once fed, do not appear to live long after leaving the host. Thus 2 males removed from the host a month after the females had dropped lived less than a month, one dying in 10 days, although kept under the most favorable conditions.

This species attaches largely to the head, particularly to the ears both on the inside and outside.

LIFE CYCLE.

Larvæ may live for 6 months during the winter and for 112 days in summer; they engorge as soon as 3 days after application to a host and molt as soon as 7 days after dropping. A total effective temperature of 399° F. is necessary to produce this molt. Nymphs engorge as soon as 5 days after application and molt as soon as 17 days after dropping, a total effective temperature of 694° F. being required to produce this transformation. Adults may live for 388 days; they mate upon the host, may engorge as soon as 14 days after attachment, and begin ovipositing the third day after dropping. Eggs hatch as soon as 21 days after deposition, a total effective temperature of 793° F. being required for incubation. Although adults may be found at any time during the year they appear to be much more numerous in the summer and early fall than at other seasons. The nymphs are to be found in considerable numbers upon birds in February and March.

ECONOMIC IMPORTANCE.

In the sections where this tick occurs in any numbers it is the source of great annoyance to domestic animals, particularly to cattle. By attaching to the inside of the ears, as frequently occurs, great irritation is caused; in the case of calves, this irritation is sufficient to cause suppuration and the formation of large scabs. The injury in the ears furnishes opportunity for the screw-worm fly (*Chrysomyia macellaria*) to deposit its eggs, which in the case of equines sometimes results in the destruction of the cartilage, thus causing the ears to droop—a condition known as "gotched" ears. The species is also of some importance on account of the fact that it sometimes attacks man.

NATURAL CONTROL.

The natural enemies of the cattle tick undoubtedly destroy many ticks of this species.

ARTIFICIAL CONTROL.

The longevity and numerous hosts of this tick make starvation impractical. Where the injury is sufficiently great to warrant artificial checks, hand picking, mopping, or dipping should be resorted to. Animals should be treated as often as every 12 days in order to prevent the females from engorging.

THE LONE STAR TICK.

Amblyomma americanum (Linnæus).

This species receives its common name from the silvery spot on the apex of the scutum of the female.

DESCRIPTIVE.

Adult (Pl. XI, figs. 2, 3, 5–10).—Males from 2.5 by 1.5 mm. to 3.5 by 2.5 mm. Females, unengorged, 3.5 by 2 mm. to 4 by 2.25 mm.; engorged, 10 by 9 by 5 mm. to 15 by 12 by 8 mm. Color brown; posterior lobe of the scutum of the female with a large silvery white spot; the dorsum of the male also has silvery white markings around its posterior margin.

Nymph (Pl. XI, fig. 4).—Unengorged, about 1.5 by 1.25 mm.; light brown, with much yellow (fulvous), scutum somewhat darker; the intestines, which show through, appear to be of a dark brown color; length of capitulum 0.41 mm. (from tip of palpi to base of emargination of scutum); scutum 0.86 mm. long by 0.699 mm. wide; engorged, about 4 by 2.5 mm. in the larger specimens, which usually become females, and 3 by 2 mm. in the smaller, which usually become males; color dark gray. The silvery white markings of the males and females do not become visible until a day or two prior to the shedding of the skin.

Larva (Pl. XI, fig. 1).—Unengorged, 0.64 by 0.51 mm.; length of capitulum 0.185 mm. (from tip of palpi to base of emargination of scutum); scutum 0.235 mm. long by 0.332 mm. wide; body ovoid, brown, lateral margin of scutum darker brown. Engorged, 1.5 by 1 mm., ovoid. Most of the larvæ as they drop engorged are dark brown, shining, but some have a pink color.

Egg.—Ellipsoidal, yellowish brown to pale yellow, or pale brownish yellow, shining, smooth. The maximum size of 10 was 0.570 by 0.431 mm.; minimum size 0.514 by 0.416 mm.; average size 0.544 by 0.419 mm.

HOST RELATIONSHIP.

The type host for this species is not known. The species has a wide range of hosts, apparently attaching to almost any mammal with which it comes in contact. It has also been taken from birds. In about 75 records of collections of this species in the southwestern part

of the United States, largely in Texas, the frequency of occurrence on different hosts was as follows: Dog 23, cattle 11, man 9, horse 9, deer 4, goat 3, peccary 2, hog 2, mule 2, skunk 2, sheep 1, wolf 1, fox

FIG. 11.—The lone star tick, *Amblyomma americanum:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the species. (Original.)

squirrel 1, badger 1, domestic cat 1, wild turkey 2, and chaparral cock 1.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 11.)

The type locality for this species is Pennsylvania or New Jersey. The Marx collection contains one unengorged female from Labrador. The species has been collected from nearly all of the States bordering

upon the Atlantic Ocean and Gulf of Mexico and from several inland States, including Michigan, Kentucky, Missouri, Arkansas, and Oklahoma. It is also reported to have been collected in Guatemala, Guiana, and Brazil. The species is very abundant in a large part of the States of Texas and Louisiana.

LIFE HISTORY.

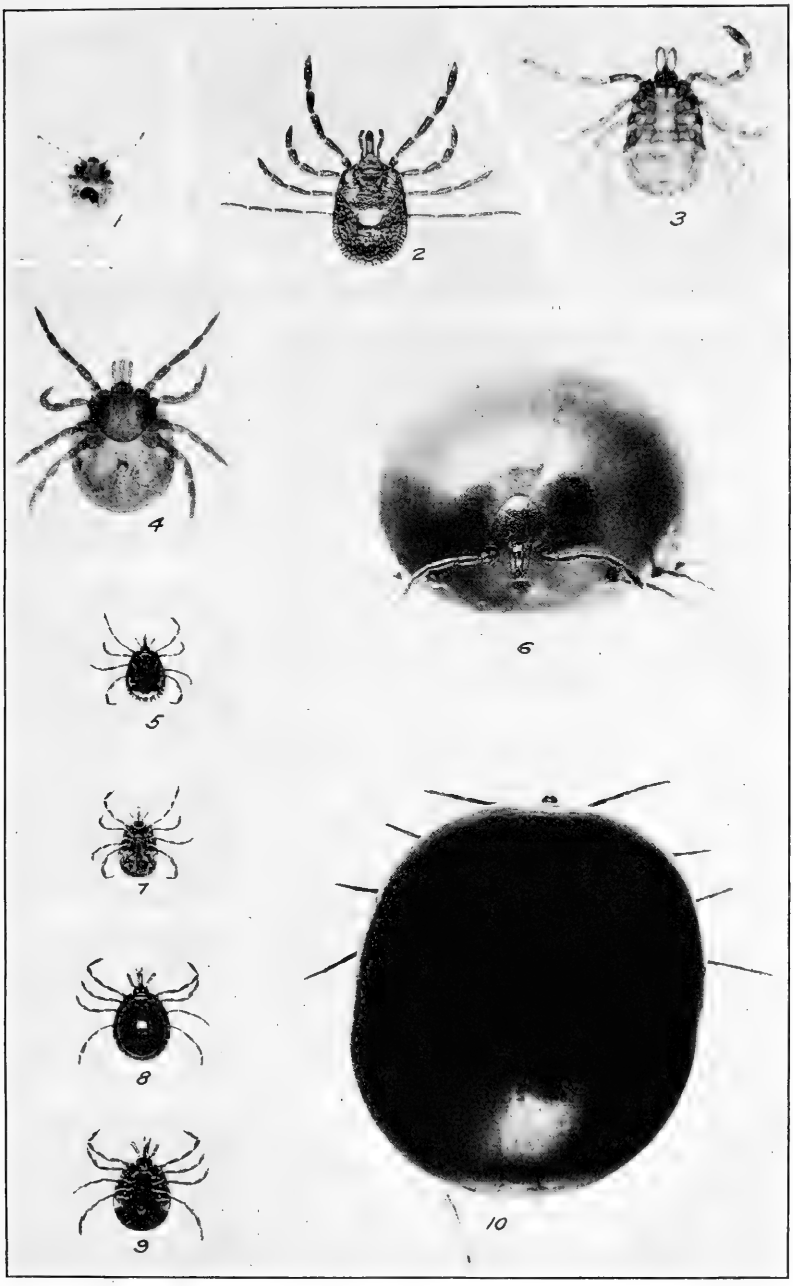
Information on the biology of this species has been published by Leidy (1891), Morgan (1899), Hunter and Hooker (1907), and by Hooker (1908).

The egg (Tables LVIII, LIX).—In the laboratory in June at a mean temperature of 87.7° F. oviposition commenced as early as the fifth day from dropping, while out of doors in July and August at a mean temperature of about 81° F. seven or more days were required. The longest preoviposition period recorded was 13 days. At a mean temperature of 80° F. one tick continued oviposition for 23 days. This individual, however, was one of the largest met with (measuring 15 by 12 by 8 mm.) and deposited the maximum number of eggs recorded for the species, namely, 8,330 eggs between May 25 and June 16. The maximum, minimum, and average preoviposition period for 12 ticks, the deposition of which is recorded in Table LVIII, was 9, 5, and 7 days, respectively. The maximum, minimum, and average oviposition period for these ticks was 23, 8, and 13.25 days, respectively, and the average number of eggs deposited was 3,053.5 per tick.

TABLE LVIII.—*Oviposition of Amblyomma americanum.*

Date engorged female dropped.	Number of eggs deposited—days following dropping.											
	6	7	8	9	10	11	12	13	14	15	16	17
1906.												
April 27	0	0	110	74	31	118	89	230	399	503	464	338
May 15	0	0	0	0	178	383	583	213	465	356	230	73
Do	0	0	390	417	656	835	963	50	(1)	572	229	201
Do	0	(1)	414	285	504	594	361	210	(1)	156	66	55
Do	0	0	193	301	409	271	197	82	(1)	144	24	64
Do	0	0	180	187	209	144	99	57	(1)	53	14	4
Do	0	0	58	206	380	368	187	53	(1)	118	36	36
Do	0	0	42	201	307	264	197	110	(1)	89	41	39
1908.												
May 6	0	0	0	0	54	435	464	501	496	622	323	342
Do	0	0	0	0	32	445	439	589	248	745	219	239
May 7	0	57	270	265	367	335	420	354	364	330	195	67
May 19	(1)	460	757	766	805	730	808	714	647	615	467	635

[1] The eggs laid on this day are included with those recorded under the following day.



THE LONE STAR TICK, AMBLYOMMA AMERICANUM.

Fig. 1.—Unengorged larva. Fig. 2.—Unengorged female, dorsal view. Fig. 3.—Male (balsam mount). Fig. 4.—Unengorged nymph (balsam mount). Fig. 5.—Male, dorsal view. Fig. 6.—Engorged female, frontal view. Fig. 7.—Male, ventral view. Fig. 8.—Unengorged female, dorsal view. Fig. 9.—Unengorged female, ventral view. Fig. 10.—Fully engorged female, dorsal view. (Original.)

TABLE LVIII.—*Oviposition of Amblyomma americanum*—Continued.

Date engorged female dropped.	Number of eggs deposited—days following dropping. 18	19	20	21	22	23	24	25	26	27	28	Total number of eggs.
1906.												
April 27	212	132	112	70	0	Dead	......	....	....	....	....	2,882
May 15	0	0	0	27	0	...do...	......	....	....	....	....	2,508
Do	148	129	0	0	Dead	......	......	....	....	....	....	4,590
Do	14	0	0	0	...do...	......	......	....	....	....	....	2,659
Do	25	17	6	3	0	0	......	....	....	....	....	1,736
Do	0	0	0	0	Dead	......	......	....	....	....	....	947
Do	25	20	16	5	2	0	......	....	....	....	....	1,510
Do	6	10	0	0	Dead	......	......	....	....	....	....	1,306
1908.												
May 6	196	103	106	90	19	0	Dead	....	....	....	....	3,751
Do	162	54	2	0	0	0	...do...	....	....	....	....	3,174
May 7	74	67	79	5	0	0	...do...	....	....	....	....	3,249
May 19	186	203	153	100	76	58	51	38	25	22	14	8,330
Average	......	......	......	......	......	......	......	....	....	....	....	3,053.

The minimum incubation period recorded occurred in the laboratory in June and July at a mean temperature of 80.5° F. This period was 23 days, while out of doors in July and August, at a mean temperature of 82.5° F., 32 days passed before hatching commenced. The total effective temperature required for embryonic development appears to be 862° F.

TABLE LIX.—*Preoviposition, incubation, and larval longevity of Amblyomma americanum.*

Date engorged female dropped.	Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation. Maximum.	Minimum.	Average daily mean.	Total effective temperature.
	1906.		Days.	1906.	Days.	°F.	°F.	°F.	°F.
	May 28, 29	Before July 1	34	Nov. 27	150	......	......	......	......
	May 30, 31	July 1 or before	32	Nov. 27	150	......	......	......	......
1907.	1907.	1907.							
Mar. 30	Apr. 12	June 13	63	......	......	......	......	......	......
June 18	June 25	July 22	28	......	......	......	......	......	......
	1908.	1908.		1908.					
	May 14, 18	June 11	29	Sept. 30–Oct. 7	110–115	89.0	65	78.5	1,028
	May 19–27	June 15	28	Oct. 16–24	123–131	91.5	68	79.7	1,018
	May 27–29	June 21	26	Before Sept. 24	95	91.5	69	80.4	972
	May 30	June 24	26	Sept. 30–Oct. 7	98–105	91.5	69	81	986
	May 31–June 3	June 26	27	Sept. 25	91	91.5	69	81.2	1,019
	June 4–6	June 29	26	Oct. 26	119	91.5	69	80.8	983
1909.	1909.	1909.		1909.					
June 4	June 10	July 4	25	......	......	91.0	69	80.2	930
	June 11	July 3	23	Sept. 2–15	61–74	91.0	70	80.5	862
	June 9	July 3	25	Aug. 20–Sept. 2	48–61	91.0	69	80.3	932
June 9	June 15	July 9	25	Sept. 4–15	57–68	90.0	71	81	950
		1910.		1910.					
Sept. 27	Oct. 11	Jan. 27	109	May 20–July 16	113–170	87.0	17	57.1	1,908
Oct. 2	Oct. 14	Feb. 7	117	July 16–Aug. 2	159–176	87.0	17	56	1,949
	1908.	1908.		1909.					
(1)	July 14	Aug. 14	32	Apr. 19	279	97.5	60	82.3	1,256
(1)	July 16	Aug. 16	32	Jan. 28–Feb. 8	196–207	97.5	60	82.5	1,262
(1)	July 17	Aug. 17	32	Dec. 24 (1908)–Jan. 23	160–190	97.5	60	82.5	1,264

[1] Records made out of doors.

The larva (Tables LIX–LXI).—As is shown in Table LIX, the greatest longevity of larvæ observed by us was 279 days. This record was made on ticks kept in a tube in a protected place out of doors. The longevity of larvæ kept in the laboratory did not exceed 176 days and usually ranged between two and four months. Larval engorgement was completed as soon as 3 days, the greatest number dropping from the host on the fourth day. The longest period required for engorgement was 9 days; this, however, may be explained through the failure of the ticks to attach at once or because they attached at a point where the blood supply was poor.

TABLE LX.—*Engorgement of larvæ of Amblyomma americanum.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
July 12, 1907, 3 p. m.	Bovine	0	0	80	177	7	0	0	0	0	0	264
Apr. 6, 1908, 4 p. m.	...do	0	0	0	0	6	6	0	2	1	0	15
July 27, 1908, 5 p. m.	...do	0	0	0	80	13	0	0	0	0	0	93
Aug. 31, 1908, 3 p. m.	Rabbit	0	0	0	61	21	10	4	0	0	0	96
Aug. 16, 1909	Bovine	0	0	0	0	11	10	0	0	0	0	21

The rapidity of engorgement is shown in Table LXI:

TABLE LXI.—*Rapidity of engorgement of larvæ of Amblyomma americanum applied to bovine at 3 p. m., July 12, 1907.*

Date engorged larvæ dropped (bags examined).	Number.	Period from application.	Per cent of total dropped.
1907.		*Hours.*	
July 15, 11 a. m.	26	68	9.8
July 15, 3 p. m.	51	72	19.3
July 15, 4.30 p. m.	3	73½	1.2
July 16, 10 a. m.	104	91	39.4
July 16, 1.30 p. m.	69	94½	26.1
July 16, 5 p. m.	4	97½	1.5
July 17, 10 a. m.	5	114½	1.9
July 17, 2 p. m.	2	118½	.8
July 17, 5 p. m.	0	....	....
Total	264	....	....

Our observations of the molting of engorged larvæ were made on 326 individuals. In July and August at a mean temperature of 86.78° F. molting commenced in 8 days. A total effective temperature of 350° F. appears to be required for this transformation. The longest period recorded from dropping to molting was 26 days. During winter this period would undoubtedly be much longer.

The nymphs (Tables LXII–LXIV).—The most complete information at hand on the longevity of nymphs was obtained in an experiment in which 30 nymphs that molted June 23–26, 1907, were kept out of doors in a tube that had a cork stopper, through which a small hole had been made and a small glass tube inserted to permit

an equalization of the humidity content of the air. Over the small glass tube a cotton cloth was tied to prevent the escape of the ticks. The records show that on May 6, 1908, 6 were alive and very active; from July 28 to August 29, 5 were found alive; from September 3 to September 10, 4; from September 18 to September 23, 3; from September 28 to October 1, 2. The sole survivor died on October 11, 1908, a period of 476 days or 15½ months after having transformed to a nymph.

TABLE LXII.—*Longevity of nymphs of Amblyomma americanum.*

Date molted or collected.	Number.	Date last larva died.	Nymphal longevity.
			Days.
June 23-26, 1907, molted	30	Oct. 11, 1908	476
Aug. 11, 1908, molted	6	Apr. 18, 1909, 1 alive	240+
Sept. 2, 1908, molted	6	June 24 to July 13, 1909	295-314
Sept. 21, 1908, molted	3	Jan. 30 to Feb. 23, 1909	131-155
Sept. 21-23, 1908, molted	4	Jan. 22 to Feb. 12, 1909	121-144
Aug. 31 to Sept. 5, 1909, molted	15	Feb. 15, 1910, 9 alive	189-196+
Sept. 2, 1909, collected	10	Feb. 28 to May 20, 1910	207-260

The shortest period in which engorgement took place was three days, the majority dropping from the third to fifth days.

TABLE LXIII.—*Engorgement of nymphs of Amblyomma americanum.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.										Total number dropped.
		1	2	3	4	5	6	7	8	9	10	
July 27, 1907	Dog	0	0	2	0	0	0	0	0	0	0	2
July 31, 1907, 2 p. m.	Bovine	0	0	14	3	0	0	0	0	0	0	17
June 15, 1908, 5 p. m.	do	0	0	0	0	1	1	0	1	0	0	3
Aug. 20, 1908, 6 p. m.	do	0	0	4	8	7	0	0	0	0	0	19
Aug. 31, 1908, 3 p. m.	Rabbit	0	0	0	7	3	0	0	0	0	0	10
Mar. 15, 1910	Bull	0	0	0	0	0	1	0	1	0	0	2
Sept. 7, 1910	do	0	0	1	0	2	1	0	2	0	0	6

In August, 1907, molting commenced on the thirteenth day. In August, 1908, at a mean temperature of 84° F. molting commenced as soon as 16 days after dropping, a total effective temperature of 657° F. being required. The longest period from dropping to molting recorded was 46 days. Winter temperatures lengthen the molting period considerably.

TABLE LXIV.—*Molting of engorged nymphs of Amblyomma americanum.*

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.																	
			13	15	16	17	18	19	20	21	22	23	24	25	26	28	31	32	45	46
Aug. 3, 1907	Bovine.....	14	0	2♂	{1♂ 5♀	1♂ 3♀}	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 4, 1907	.....do.......	3	1♂	0	2♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 16, 1908	Horse........	1	0	0	0	0	0	1♀	0	0	0	0	0	0	0	0	0	0	0	0
June 20, 1908	Bovine.......	1	0	0	0	0	0	0	0	1♂	0	0	0	0	0	0	0	0	0	0
June 21, 1908	.....do.......	1	0	0	0	0	0	0	1♂	0	0	0	0	0	0	0	0	0	0	0
June 23, 1908	.....do.......	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♀
Aug. 21, 1908	Dog..........	4	0	0	0	{1♂ 1♀}	2♀	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 23, 1908	Bovine.......	4	0	0	0	3♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 24, 1908	.....do.......	8	0	0	0	{1♂ 1♀}	1♂	{1♂ 1♀}	1♂	1♂	1♂	0	0	0	0	0	0	0	0	0
Aug. 25, 1908	.....do.......	7	0	0	1♂	1♂	1♂	{2♂ 1♀}	1♀	0	0	0	0	0	0	0	0	0	0	0
Sept. 4, 1908	Rabbit.......	6	0	0	0	0	0	0	0	0	1♀	2♀	{1♂ 1♀}	0	0	0	0	0	0	0
Sept. 2, 1909	Bovine.......	12	0	0	1♂	1♂	{4♂ 4♀}	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 10, 1909	Bull..........	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1♂	0	0	0	0
Sept. 12, 1909	.....do.......	2	0	0	0	0	0	0	0	0	0	0	0	2♀	0	0	0	0	0	0
Sept. 13, 1909	.....do.......	1	0	0	0	0	0	0	0	0	0	0	0	1♀	0	0	0	0	0	0
Sept. 15, 1909	.....do.......	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♀	1♀	0	0
Mar. 21, 1910	.....do.......	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♂	0
Mar. 23, 1910	.....do.......	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1♂	0
Total..	....	70																		

[♂ = Male. ♀ = Female.]

Date engorged nymphs dropped.	Host.	Number.	Number molted.			Temperature from dropping to date first tick molted.		
			Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
						°F.	°F.	°F.
Aug. 3, 1907	Bovine............	14	4	8	12	....	....	....
Aug. 4, 1907	.....do...........	3	1	2	3	....	....	....
June 16, 1908	Horse.............	1	0	1	1	90.0	70.5	80.96
June 20, 1908	Bovine............	1	1	0	1	93.5	70.5	81.52
June 21, 1908	.....do...........	1	1	0	1	93.5	70.5	81.57
June 23, 1908	.....do...........	1	0	1	1	99.0	75.0	83.60
Aug. 21, 1908	Dog...............	4	1	3	4	97.5	75.0	83.72
Aug. 23, 1908	Bovine............	4	0	3	3	97.5	75.0	83.96
Aug. 24, 1908	.....do...........	8	6	2	8	97.5	75.0	84.04
Aug. 25, 1908	.....do...........	7	5	2	7	97.5	75.0	84.19
Sept. 4, 1908	Rabbit............	6	1	4	5	97.0	70.0	81.1
Sept. 2, 1909	Bovine............	12	6	4	10	101.0	68.5	86.6
Sept. 10, 1909	Bull..............	1	1	0	1	101.0	56.0	79.3
Sept. 12, 1909	.....do...........	2	0	2	2	98.5	56.0	75.6
Sept. 13, 1909	.....do...........	1	0	1	1	96.5	56.0	75.2
Sept. 15, 1909	.....do...........	2	0	2	2	95.5	52.5	75.6
Mar. 21, 1910	.....do...........	1	1	0	1	92.0	43.0	86.2
Mar. 23, 1910	.....do...........	1	1	0	1	89.0	43.0	86.2
Total..	....	70	29	35	64	....	....	....

The adult (Tables LXV–LXVI).—The greatest longevity of adults recorded was between 393 and 430 days. The longevity records given below were based upon adults kept in cotton-stoppered glass tubes on moist sand in the laboratory. It is quite probable that the longevity would have been greater had the ticks been kept out of doors. The females appear to live longer usually than the males. The first lot of ticks recorded in the table is the only one in which the last surviving tick was a male.

TABLE LXV.—*Longevity of adults of Amblyomma americanum.*

Date nymphs molted to adults.	Number.			Date last tick died.	Longevity.
	Total.	Male.	Female.		
					Days.
June 5, 1908	3	2	1	Dec. 26, 1908	207
Sept. 1, 1908	8	1	7	May 15-June 8, 1909	256-280
Sept. 11, 1908	10	6	4	Jan. 22-Feb. 18, 1909	133-160
Sept. 26-28, 1908	5	1	4	Aug. 20, 1909, 1 female alive	326-328+
Sept. 10-20, 1909	11	4	7	Oct. 18-Nov. 14, 1910	393-430
Oct. 7-17, 1909	6	1	5	Aug. 18-Sept. 26, 1910	305-354

Mr. J. D. Mitchell once observed this species in copulation on herbage but we have no other record of such a habit. Ticks which have been kept together in tubes have never been observed in copulation. When unfed ticks are placed upon a host, attachment usually takes place at once, the sexual instinct being manifested only after several days feeding. Fertilization may be necessary for engorgement, as females which have been collected from vegetation have attached readily, but in the absence of males have failed to engorge and have died about a month after attachment. Males placed upon the bovine scrotum upon which females of other species were attached have been found in coitu with other species (*Margaropus annulatus australis, Amblyomma maculatum*, and *Dermacertor nitens*) even though females of *americanum* have been attached upon the scrotum at the same time. They have, however, remained in the position of copulation with other species for periods less than 24 hours. The eggs deposited by unfertilized females are dark and shriveled up. Our observations seems to indicate that only a short time is required for the fertilization of the female as males remain in copulation for a few hours at a time, then pass to other females, or return to the same female. They are frequently found mated with fully engorged females.

Males have remained upon the scrotum for more than two and one-half months, or a month and a half after the females dropped. Females collected from a host, if not more than one-half engorged, will attach to a second host, and if fertilized while on the first host become engorged in a comparatively short time. The minimum period in which engorgement has taken place is found to be 11 days, while slightly engorged reattached ticks which had probably been fertilized while upon the first host completed engorgement in 2 days. The longest period required for engorgement was 24 days. The length of the engorgement period does not appear to influence the size of the engorged female.

TABLE LXVI.—*Engorgement of females of Amblyomma americanum on bovine.*

Adults applied.	Engorged females dropped—days following application.														Total number dropped.
	2	3	4	5	7	8	9	10	11	14	15	16	20	24	
Mar. 28, 1907, 4 p. m [1]	1														1
Mar. 22, 1907, 9 a. m [2]			1												1
Aug. 31, 1907, 5 p. m.									1		1	2	1	1	6
May 5, 1908 [3]										1					1
June 29, 1908 [3]				1	1	1		2							5
Aug. 24, 1908 [4]			1												1
June 1, 1909. [3]		1	1	2		1									5
Sept. 18, 1909 [3]							1			2					3

[1] This tick was collected Mar. 25, 1907. It was slightly engorged, measuring 5.5 by 4 mm.
[2] This tick was slightly engorged (5 by 4 mm.) and probably fertilized when collected.
[3] These were collected on a host but were not perceptibly engorged.
[4] This tick was taken from a host and was slightly engorged.

LIFE CYCLE.

Larvæ may live as long as 279 days; they may engorge as soon as 3 days and in summer molt as soon as 8 days, a total effective temperature of 350° F. being required. Nymphs may live 476 days; they engorge as soon as 3 days and may molt 13 days after dropping. A total effective temperature of 657° F. appears to be necessary to produce this molt. Adults may engorge in 9 days, commence depositing 5 days later, and deposit as many as 8,330 eggs. The eggs hatch as soon as 23 days, requiring an effective temperature of 862° F. for incubation.

ECONOMIC IMPORTANCE.

This species is of considerable economic importance as an external parasite. It readily attaches to domestic animals and man. As its mouth parts are long and permit of deep penetration, the attachment of the tick causes considerable inflammation which frequently ends in suppuration. In Texas and Louisiana, where this species is abundant, cattle in particular suffer from heavy infestation. In the Eastern and Southern States man is more frequently attacked by this than any other species. Moss gatherers in Louisiana are greatly annoyed by its attacks (Morgan, 1899). At dairies milkers are annoyed, particularly by the males which leave the cows and attach to them. This tick may attach in the ears and be the indirect cause of "gotch" in donkeys. Mr. J. D. Mitchell has observed that on hogs this tick attaches by preference to the belly, where even in the case of engorged ticks, the swelling of the skin is sufficient to almost hide them. Suppurating pustules were observed on this host where the ticks had dropped off. Attempts to transmit Texas fever by this tick have failed (Mayo, 1897; Morgan, 1899).

A correspondent in south-central Missouri reports that this tick is a serious pest to poultry there. The larvæ attack young chickens in such numbers as to kill them. He also states that the larvæ and adults are very annoying to man and domestic animals.

NATURAL CONTROL.

In order to determine the effect of water seven partially engorged females were submerged May 29, 1906, for 18 hours. After removal all became active and on May 30 were again submerged for 45 hours, only one surviving. As yet no parasites have been found to attack this tick. The natural enemies of the cattle tick, as described in Bulletin 72, undoubtedly destroy large numbers of this species.

ARTIFICIAL CONTROL.

Owing to the great longevity of the nymphs and adults, and to the many hosts which this species attacks, the rotation method of eradication is impracticable. Frequent mopping or dipping with any of the standard tick dips must be resorted to. To be effective, mopping, dipping, or hand picking should be practiced often enough to destroy the females before they become engorged; that is, every 10 days.

THE CAYENNE TICK

Amblyomma cajennense (Fabricius).

DESCRIPTIVE.

The common name of this species is taken from the locality in which it was first collected and from which the specific name was taken; that is, Cayenne, Guiana.

Adult (Pl. XII, figs. 2, 3, 5–7).—Males from 3 by 1.75 mm. to 4 by 2.50 mm. Females, unengorged, 3.5 by 2 mm. to 4.25 by 2.5 mm.; engorged, from 10 by 7 by 4 mm. to 12 by 8 by 6 mm. Males pale yellow or brownish yellow, with irregular silvery white markings or streaks, and brown or reddish brown spots, all arranged to form a definite but complex pattern. Unengorged female yellowish; scutum largely silvery, with a brown line on each margin reaching back from the eyes. Engorged females dull bluish gray, with dark purplish brown reticulations.

Nymph (Pl. XII, fig. 4).—Unengorged, 2 by 1.25 mm.; engorged, from 3.25 by 2 mm. to 4 by 2.75 mm.; length of capitulum 0.407 mm. (from tip of palpi to base of emargination of scutum); scutum 0.561 mm. long by 0.786 mm. wide. Upon emerging the nymphs are of a dark-brown color; this soon turns to light brown, with intestinal markings showing through as dark-brown bands. As with *americanum,* the sex of the nymph can be told a day or two prior to molting by the silvery markings which show through the to-be-molted skin.

Larva (Pl. XII, fig. 1).—Unengorged, 0.65 by 0.51 mm., yellowish, the scutum marked on the lateral margins with dark red; engorged, 2.5 by 2 mm., ovoid, bluish gray. Length of capitulum 0.195 mm. (from tip of palpi to base of emargination of scutum); scutum 0.248 mm. long by 0.374 mm. wide.

Egg.—Ellipsoidal, deep yellowish brown, shining, smooth. The average size of 10 eggs measured was 0.487 by 0.431 mm.

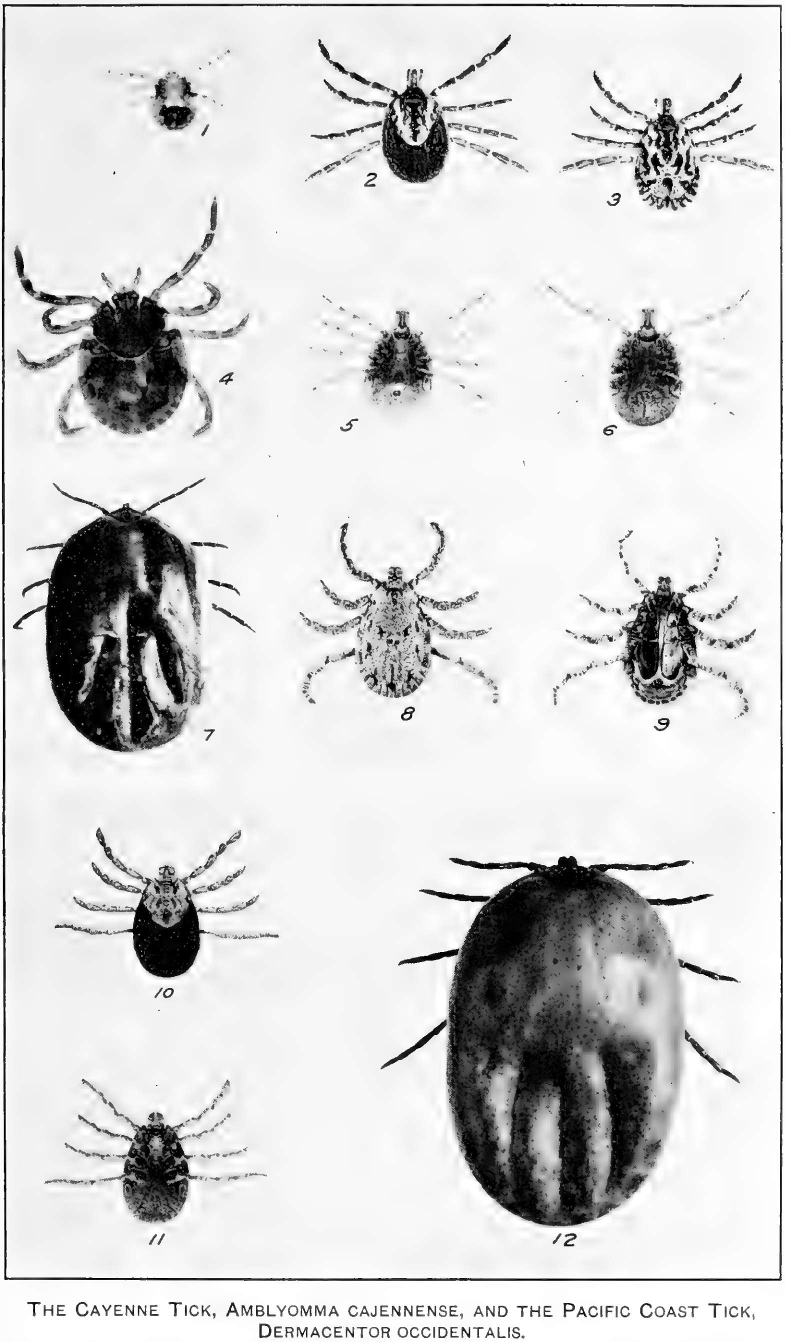
HOST RELATIONSHIP.

The type host of this tick is not known. It attaches readily to a large number of mammals, having been taken in Texas by agents of the bureau from the horse, mule, ox, goat, coyote, peccary, and man. Other hosts recorded are dog, hog, capybara, anteater, and toad. Mr. A. H. Jennings has collected this tick in Panama on the dog, horse, ox, and deer (*Odocoileus toltecus*). Mr. D. K. McMillan obtained one partially engorged female from a Mexican lion (*Felis hippolestes aztectus*) at Raymondville, Tex. On November 20, 1907, a flock of 75 goats in the vicinity of Brownsville, Tex., was examined for ticks. Larvæ of this species were found in large numbers on the ears and over the eyes of all examined, while partially engorged nymphs were occasionally found. Adults were collected in this same locality, associated with *Dermacentor nitens* in the ears of horses. However, they appear to prefer the abdomen or between the legs as places of attachment. On April 22, 1908, Mr. H. P. Wood found horses and mules at Brownsville to be badly infested by this tick. Messrs. E. A. Schwarz and F. C. Bishopp found this species to be very annoying to man in the vicinity of Tampico, Mexico. Horses appeared to be the host most commonly attacked by the adults. Newstead observed this tick in Jamaica to occur more particularly on equines and less abundantly on cattle. This has been the same in our observations. Newstead states that there are authentic records of the occurrence of this tick on the tongues of young calves. As illustrating what a great pest this tick is to man, he states that 27 adults of both sexes and swarms of larvæ were taken from his body after passing through a small native settlement in Jamaica. Stoll (1886–1893) has described a similar habit in the tick in Mexico and Central America.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 12.)

The type locality of this species is Guiana. It has been collected at several points in southern Texas by agents of the Bureau of Entomology, being particularly abundant at Brownsville. The Marx collection contains an unengorged female labeled as collected at Biscayne Bay, Fla. It seems quite probable that records of this species from Arizona are based upon a jar of ticks which are incorrectly labeled. Banks records having seen specimens from San Diego County, Cal. This is, with the possible exception of *Margaropus annulatus australis*, the most common species in Mexico and Central America. It has been reported from Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Bermuda, Cuba, Jamaica, Trinidad, Colombia, Venezuela, French Guiana, Brazil, Paraguay, and Argentina.



THE CAYENNE TICK, AMBLYOMMA CAJENNENSE, AND THE PACIFIC COAST TICK, DERMACENTOR OCCIDENTALIS.

Amblyomma cajennense: Fig. 1.—Unengorged larva. Fig. 2.—Unengorged female, dorsal view. Fig. 3.—Male, dorsal view. Fig. 4.—Unengorged nymph (balsam mount). Fig. 5.—Male, ventral view. Fig. 6.—Unengorged female, ventral view. Fig. 7.—Engorged female, dorsal view. *Dermacentor occidentalis:* Fig. 8.—Male, dorsal view. Fig. 9.—Male, ventral view. Fig. 10.—Unengorged female, dorsal view. Fig. 11.—Unengorged female, ventral view. Fig. 12.—Fully engorged female, dorsal view. (Original.)

LIFE HISTORY.

Observations on the biology of this species have been made by Hunter and Hooker (1907), Hooker (1909), Rohr (1909), and Newstead (1909).

FIG. 12.—The Cayenne tick, *Amblyomma cajennense:* Distribution in North and Central America. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the species. (Original.)

The egg (Table LXVII).—In the laboratory in August, at a mean temperature of 84° F., oviposition commenced on the ninth day following dropping while out of doors, at a mean temperature of 84° F., 11 days passed. Eight of 10 females collected April 22, 1908, and kept in the laboratory at a mean temperature of 63° F. commenced

oviposition on the eighteenth day, the other two beginning oviposition on the sixteenth and twentieth days after collection. The average preoviposition period for 13 ticks was 16.5 days and the average oviposition period was 19.7 days. In the laboratory in May, at a mean temperature of 77° F. oviposition continued for as long as 23 days. The largest number of eggs recorded was 4,789, which were deposited in the laboratory in 20 days following May 10, 1908. The largest number of eggs deposited in 1 day was 447. The average number of eggs deposited, based upon records of 13 ticks, is 3,536. All of the females used in these counts were collected individuals and may not have been completely engorged. Newstead states that Worthly has found 7,240 eggs to be deposited by an individual of this species and Rohr records 7,742 from 1 specimen. The minimum incubation period in the laboratory at a mean temperature of 80° F. was 37 days. Out of doors, at a mean temperature of 78.5° F., 54 days passed before the eggs hatched. Under similar out-of-doors conditions, when the mean temperature was 66.2° F., the incubation period was 154 days. The effective temperature required for embryonic development appears to be 1,370°. Newstead reports that at an average temperature of 75° F. incubation was completed in from 43 to 50 days.

TABLE LXVII.—*Preoviposition, incubation, and larval longevity of Amblyomma cajennense.*

Date engorged female dropped.	Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
						Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	1908.	*Days.*	1909.	*Days.*	*°F.*	*°F.*	*°F.*	*°F.*
Mar. 23...	Apr. 14 ...	June 8....	56	....	....	90	47	74.15	1,745
Mar. 30...	Apr. 15....	June 9....	56	Apr. 22–May 7.....	317–332	90	47	74.36	1,756
	Apr. 22....	June 12...	52	Nov. 9–16, 1908.....	150–157	90	47	74.66	1,647
	Apr. 24....	June 13...	51	Apr. 16–May 7.....	307–328	91.5	47	74.89	1,627
	May 8.....	June 19...	43	Jan. 13–22..........	208–217	91.5	63	78.57	1,520
	May 13....	June 21...	40	June 8–16..........	352–360	91.5	65	78.89	1,436
	May 15....	June 22...	39	June 9–24..........	352–367	91.5	67	79.35	1,418
	May 20....	June 26...	38	Before June 25......	364—	91.5	68	80.04	1.408
	May 22....	June 27...	37	June 25–July 13.....	363–381	91.5	68	80.11	1,373
	Aug. 26–28.	Oct. 9.....	45	Apr. 16...........	189	97.5	51	78.15	1,581
	1909.	1909.		1910.					
	Aug. 29-30.	Oct. 21....	54	Feb. 10–24..........	112–136	97.5	51	76,75	1,823
	May 18....	June 29...	43	May 20–July 16.....	325–382	100	47	90.53	1,897

The following are at outdoor temperature:

1908.	1908.	1908.		1909.					
Apr. 22...	May 9.....	July 1.....	54	June 30............	364	91	63	79	1,944
Apr. 22...	May 9.....	July 1.....	54	July 4.............	368	91	63	79	1,944
Apr. 22...	May 9.....	June 30...	53	June 15............	350	91	63	78.98	1,907
Apr. 22...	May 9.....	June 30...	53	June 18............	353	91	63	78.98	1,907
Apr. 22...	May 9.....	June 30...	53	Apr. 14............	288	91	63	78.98	1,907
		1909.							
Aug. 17...	Aug. 28...	Jan. 28....	154	Mar. 26............	57	99	17	66.23	3,422

The larvæ (Tables LXVII, LXVIII).—The greatest longevity of larvæ observed by us was 386 days. These larvæ hatched June 24, 1908, and were kept in a tube on moist sand in the laboratory. As is shown in Table LXVII, the greatest longevity out of doors was 368 days. In many cases we have observed a few larvæ to be alive over a year after the first eggs deposited by the parent had hatched. The minimum period required for engorgement was 3 days, the greatest number dropping on the fourth day. Newstead states that on man engorgement is completed in from 2 to 4 days.

TABLE LXVIII.—*Engorgement of larvæ of Amblyomma cajennense on bovine.*

Date larvæ applied.	Larvæ dropped engorged—days following application.										Total number dropped.
	1	2	3	4	5	6	7	8	9	10	
July 26, 1907	0	0	20	63	9	0	0	0	0	0	92
July 2, 1908	0	0	0	56	40	3	0	0	0	0	99
May 24, 1909	0	0	0	12	17	30	4	0	0	0	63
July 8, 1909	0	0	0	22	22	0	0	0	0	0	44
July 14, 1909	0	0	0	18	64	0	0	0	0	0	82
Sept. 2, 1909	0	0	0	185	77	20	0	0	0	0	282
Feb. 25, 1910	0	0	0	0	8	17	0	0	0	0	25

A few days after dropping the larvæ cluster together, as in *americanum*, and become quiescent. Soon the anterior part of the body becomes light colored, showing that metamorphosis is taking place. The shortest period in which molting took place was (at a mean temperature of 89.8° F.) 10 days. In this instance a total effective temperature of 468° F. was accumulated. All of the larvæ observed were engorged on bovine animals except three lots which were engorged on guinea pigs.

The nymph (Table LXIX).—In order to determine the longevity of nymphs, 20 that molted July 29, 1907, were isolated in a tube. On November 13, 1907, all were alive; on March 15, 1908, 15 remained active; on July 12, 12 were alive, and on July 29, 8 were alive. On September 5, 1908, 5 were still alive, after a period of 1 year and 43 days. Another lot of 40 nymphs which molted from larvæ September 29 to October 5, 1908, contained 1 individual which lived until June 21, 1909, a period of 265 days. In a third lot which became nymphs September 28, 1908, 5 specimens were alive after a period of 269 days.

The shortest period in which engorgement took place was 3 days, the largest number dropping on the fourth and fifth days.

TABLE LXIX.—*Engorgement of nymphs of Amblyomma cajennense.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.											Total number dropped.
		1	2	3	4	5	6	7	8	9	10	13	
Aug. 19, 1907	Bovine	0	0	2	5	3	3	0	0	0	0	0	13
Oct. 9, 1907	do	0	0	0	0	18	2	1	1	0	0	0	22
July 25, 1908	do	0	0	2	12	7	0	0	0	0	0	0	21
June 14, 1909	do	0	0	1	2	6	0	4	1	0	0	0	14
July 7, 1909	do	0	0	0	0	5	0	0	3	0	0	0	8
Aug. 5, 1909	do	0	0	0	29	6	0	1	0	2	0	0	38
Aug. 26, 1909	do	0	0	0	4	2	0	0	0	0	0	0	6
Dec. 15, 1909	Guinea pig	0	0	0	0	0	0	0	0	0	0	1	1
Feb. 25, 1910	Bovine	0	0	0	0	1	2	0	0	0	0	0	3
Apr. 25, 1910	do	0	0	0	4	0	0	0	0	0	0	0	4

In August, 1909, at a mean temperature of 89.5° F., molting commenced as soon as the twelfth day from dropping. The longest time observed to be required for molting was 105 days. During this period the mean temperature was about 53° F. An effective temperature of 558° F. appears to be required for molting.

The adult (Table LXX).—Of 103 individuals, the sex of which was determined at the time of molting, 65, or 63 per cent, were females. The greatest longevity among adults observed by us was about 466 days. This was the record of a single female which, together with 5 males, was kept on moist sand in the laboratory. These specimens molted in September, 1907. The last male died about December 1, 1908, while the female lived until December 25 of that year. One of 6 females which molted May 20–26, 1908, lived between 381 and 392 days. In another instance a male and a female which became adult September 11–13, 1909, died between 340 and 380 days later. The longevity of 7 other lots of ticks observed during 1908–1910 ranged from 133 to 366 days. All were kept in the laboratory and were not fed as adults. The length of life of males and females appears to be about the same.

Mating, so far as known, takes place only on the host. When placed upon a host the males and females attach readily. In one case a female was observed to remain in the bag covering the scrotum 5 days before attaching. However, they usually attach within 24 hours. Several days, and frequently a week or more, of feeding appear to be required before the male goes in search of a mate. In our observations the males have remained mated for only 2 or 3 days, and often a shorter period, before leaving in search of other mates.

The shortest period in which a female engorged was 7 days and the longest 12 days. One male which was placed on the scrotum of a bull July 27, 1909, attached immediately. It was not observed to copulate with the females, but reattached several times. It was still attached on September 29, a period of 64 days after application and 41 days after the last female, put on the host at the same time, had dropped engorged. During the period while this male was attached

a second lot of females was applied and had become engorged. When attached the entire length of the hypostome is buried in the flesh, the palpi bending back and touching the anterior part of the scutum.

TABLE LXX.—*Engorgement of females of Amblyomma cajennense on bovine.*

Adults applied.	Date of attachment.	Engorged females dropped—days following attachment.						Total number dropped.
		7	8	9	10	11	12	
Sept. 30, 1907		1			1			2
Mar. 19, 1908						4	1	5
July 5, 1909	July 6–7			1		1		2
July 27, 1909	July 29–Aug. 1		1			1		2
Sept. 18, 1909	Sept. 18–19					2	1	3
Do	Sept. 24	1						1
	Total							15

LIFE CYCLE.

Larvæ may live as long as 386 days. In summer they may engorge in 3 days and molt as soon as 10 days after dropping. A total effective temperature of 468° F. appears to be required for this transformation. Nymphs may live more than 13½ months if they do not find a host; they engorge as soon as 3 days and molt as soon as 12 days after dropping. The nymphal molt requires an accumulation of 558° F. of effective temperature. Adults may live as long as 466 days if they do not find a host; they may engorge as soon as 7 days after attachment, commence ovipositing 9 days later, and deposit as many as 4,789 eggs. The eggs require 1,370° F. of effective temperature for incubation.

ECONOMIC IMPORTANCE.

In this country *cajennense* is of economic importance in the lower Rio Grande Valley of Texas only. In the vicinity of Brownsville it is very abundant at certain seasons of the year and is the source of great annoyance to horses, mules, cattle, and other domestic animals. Stoll (1890) states that in Guatemala the larvæ of this tick hang on the grass in clusters of thousands, and are the source of great annoyance to travelers. The collection of the Bureau of Entomology contains many specimens taken by Schwarz and Barber in Guatemala, upon their bodies. December 5–8, 1909, Schwarz and Bishopp found this species to be very abundant in all stages at Tampico, Mex. All stages were found in great abundance on horses, and in much smaller numbers on mules, donkeys, and cattle. The adults are especially bad pests to these animals. Many people stated that it was necessary to apply kerosene and lard to their horses at frequent intervals to lessen the number of ticks on them. While collecting insects in the vicinity of Tampico, these ticks proved very annoying. At times the trousers of Schwarz and Bishopp were covered with thousands of larvæ, many of which gained access to the skin and attached. Although much fewer in number, the bites of the nymphs

and adults were much more troublesome. While the itching was intense, none of the points of attachment became infected and therefore soon healed. In one case a nearly fully engorged larva was found under the knee, which certainly had not been attached more than 36 hours. Hunters and others who have occasion to spend considerable time in the forests complain a great deal of the attacks of this tick. Schwarz and Bishopp heard of one man whose legs were well covered with suppurating sores and who was ill from the attack of these ticks and the wounds produced by scratching. At Victoria, Tamaulipas, Mex., on December 9–10, a much smaller number of ticks were found; no larvæ were seen and horses were only lightly infested.

The Bureau of Entomology has received large numbers of males of this species from the Guinand Brothers of Caracas, Venezuela, with the statement that they are the source of great loss to the cattlemen in that country.

NATURAL CONTROL.

No observations of natural enemies of this species have been made by us. Newstead (1909) records the finding of engorged females in the stomachs of the tinkling grackle (*Quiscalus crassirostris*). He also observed parrot-billed blackbirds picking ticks, probably of this species, from the heads of horses.

ARTIFICIAL CONTROL.

As with *americanum* the large number of hosts which this species has and the long periods which they can live without a host prohibit successful control by pasture rotation. Dipping, mopping, or handpicking must be resorted to when the species becomes a pest. Dipping as often as every 8 days would be required in order to prevent the dropping of engorged adults.

Genus DERMACENTOR Koch.

Five of the nine species of the genus Dermacentor which occur in the United States have been studied and are here considered. One species, *Dermacentor venustus*, has also been studied by Ricketts and by Cooley. This latter species is the only member of the genus that has been shown to transmit disease.

Two different types of life history were found to occur in the genus. While 4 of the species studied, namely, *occidentalis*, *parumapertus* var. *marginatus*, *variabilis*, and *venustus* drop to pass both molts off the host, *nitens* does not do so but transforms upon the host. Another species (*Dermacentor albipictus*) which is now being studied has also been found to have this habit. This habit of molting upon the host, as well as the preference shown by *Dermacentor nitens* for the inside of the ears as a place of attachment, where it is considerably protected from bird and other enemies and where it is not readily removed by the host, must be considered as protective adaptations. The adults of all species of this genus which we have studied

excrete large amounts of what appears to be undigested blood, while engorging.

THE RABBIT DERMACENTOR.

Dermacentor parumapertus marginatus Banks.

The common name of this tick is taken from the fact that in the adult stage it is found on no other host than the rabbit, while the adults of other species of the genus Dermacentor are very rarely found on that host.

DESCRIPTIVE.

Adult (Pl. XIII, figs. 3–5).—Males from 2.5 by 1.25 mm. to 3 by 1.75 mm. Females, unengorged, 2.5 by 1.5 mm. to 3.75 by 2 mm.; engorged, 10 by 7 by 3.5 mm. to 15.4 by 10.7 by 7.7 mm. The males have interrupted white markings along the lateral borders of the dorsum. The posterior border of the scutum of the females is white, the lateral borders with interrupted white markings. In both sexes the outer surface at the apex of the leg segments is marked with white, in which are usually two dark red punctations. Some specimens from California, Oregon, and Utah have no white visible, while others are nearly as strongly marked as those from New Mexico and Texas.

Nymph (Pl. XIII, fig. 2).—Unengorged, about 1.23 by 0.79 mm.; engorged, 3 by 2.1 by 1.2 mm. to 3.9 by 2.8 by 1.6 mm. Color, unengorged, reddish brown; engorged, dark slate to almost black. Capitulum 0.305 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.524 mm. long by 0.521 mm. wide.

Larva (Pl. XIII, fig. 1).—Unengorged, about 0.686 by 0.433 mm. (alcoholic); engorged, 1.3 by 0.8 by 0.7 mm. to 1.5 by 0.9 by 0.8 mm. Color, unengorged, reddish yellow; engorged, dark slate. Capitulum 0.148 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.260 mm. long by 0.344 mm. wide.

Egg.—Ellipsoidal, yellowish brown, shining, smooth. The average size of 10 measured was 0.65 by 0.47 mm.

HOST RELATIONSHIP.

The host of the type variety is the jack rabbit. The types of the species (*D. parumapertus*) are labeled as taken from man and in a chicken house. No specimens of this variety have been taken on other hosts than jack rabbit and cottontail rabbit. While very few larvæ and nymphs have been collected on rabbits, it would appear from the fact that no specimens have been taken on any other animal that the rabbit is the principal host of those stages. We have engorged larvæ in our rearing experiments on the fox squirrel, guinea pig, and bovine, as well as rabbit, and nymphs have been engorged on the guinea pig and rabbit.

Although a large number of unengorged adults have been collected, very few fully engorged females have been obtained. It would seem that a large number of them are scratched off by the host before becoming replete. The species is found principally in the ears of

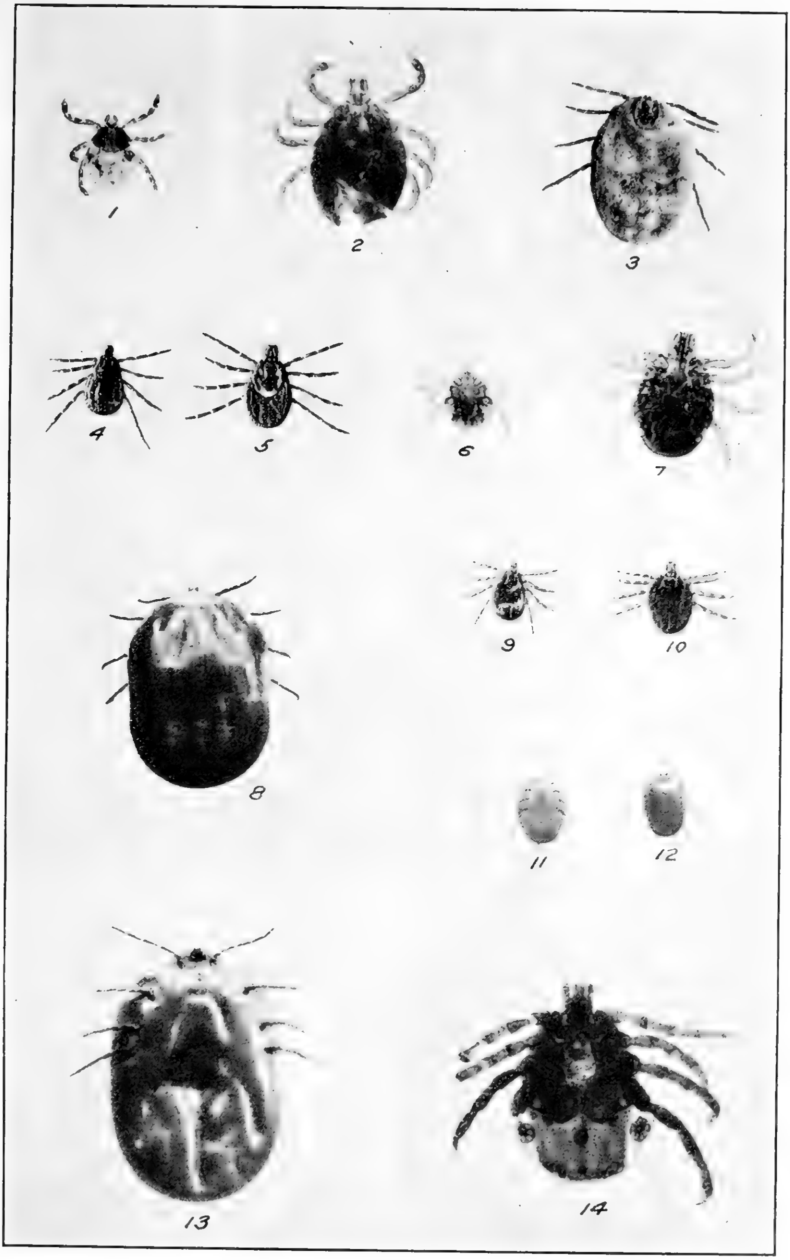
the host, but it also attaches on the outside of the ears, on the head, on the neck, and sometimes between the toes. Adults collected on rabbits have been found to attach readily to bovine hosts and to engorge to repletion.

FIG. 13.—The rabbit Dermacentor, *Dermacentor parumapertus marginatus:* Distribution. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the species in the United States. (Original.)

GEOGRAPHICAL DISTRIBUTION.

(Fig. 13.)

Mesa City, Arizona, is the type locality for this variety. The species is confined to the semiarid and arid west, including Texas west of about the 101st meridian, New Mexico, Arizona, southern Utah, Nevada, California, and southeastern Oregon. It appears to



THE RABBIT DERMACENTOR, DERMACENTOR PARUMAPERTUS MARGINATUS, AND THE TROPICAL HORSE TICK, DERMACENTOR NITENS.

Dermacentor parumapertus marginatus: Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph (balsam mount). Fig. 3.—"Deposited-out" female, dorsal view. Fig. 4.—Male, dorsal view. Fig. 5.—Unengorged female, dorsal view. *Dermacentor nitens:* Fig. 6.—Unengorged larva. Fig. 7.—Unengorged nymph (balsam mount). Fig. 8.—Engorged female, dorsal view. Fig. 9. —Male, dorsal view. Fig. 10.—Unengorged female, dorsal view. Fig. 11.—Engorged nymph, ventral view. Fig. 12.—Engorged nymph, dorsal view. Fig. 13.—Engorged female, ventral view. Fig. 14.—Male (balsam mount). (Original.)

be most abundant in western Texas and in New Mexico. Larvæ and nymphs have also been taken at Monclova, Mex.

LIFE HISTORY.

No observations on the biology of this species have been previously published.

The egg (Table LXXI).—In July at a mean temperature of 85° F. oviposition commenced as soon as the fifth day after dropping. Four of 7 ticks which dropped engorged during July and early August commenced oviposition on the fifth day, the three remaining ones commencing a day later. The average oviposition period of 7 females observed in July and August was 15.9 days. The minimum oviposition period was 11 days, within which time 855 eggs were deposited; the maximum, 26 days, during which period 3,247 eggs were laid. The maximum number of eggs recorded for the species is 4,660. The female which made this record deposited 918 eggs during one day. The females died in from 1 to 6 days after deposition was completed. One of the 7 engorged females upon which these counts of eggs were made was collected on a rabbit, while the other 6 females were engorged upon bovines. The measurements of the 6 were as follows: 10 by 7 by 4 mm., 12.5 by 9 by 6.5 mm., 12 by 8.5 by 6 mm., 11 by 7.5 by 4 mm., 10 by 7 by 5 mm., and 10 by 7 by 3.5 mm., respectively.

The shortest incubation period was 20 days, the mean temperature during this period being 85° to 86° F. A total effective temperature of at least 850° F. appears to be required for embryonic development.

TABLE LXXI.—*Incubation and larval longevity of Dermacentor parumapertus marginatus.*

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
					Maximum.	Minimum.	Average daily mean.	Total effective temperature.
		Days.		*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
June 30, 1908	July 23, 1908	24	....	....	95	70.0	81.1	954.25
July 2, 1908	July 24, 1908	23	....	....	95	70.0	83.1	959.75
July 18, 1908	Aug. 8, 1908	22	Jan. 25, 1909	170	99	76.5	85.5	935.75
July 20, 1908	Aug. 10, 1908	22	Nov. 30, 1908	102	99	73.0	85.4	916.75
July 22, 1908	Aug. 12, 1908	22	Mar. 6, 1909	223	99	73.0	85.7	922.75
July 24, 1908	Aug. 14, 1908	22	Mar. 12, 1909	227	99	73.0	85.9	944.75
July 26, 1908	.....do.......	20	Feb. 10, 1909	197	99	73.0	86.2	863.75
July 27, 1908	Aug. 16, 1908	21	Oct. 26, 1908	71	99	73.0	86.3	909.00
July 28, 1908	Aug. 17, 1908	21	Feb. 15, 1909	227	99	73.0	86.4	911.50
July 30, 1908	Aug. 19, 1908	21	Mar. 12, 1909	222	99	73.0	86.7	917.25
Aug. 3, 1908	Aug. 22, 1908	20	Dec. 6, 1908	106	99	73.0	86.2	863.50
Aug. 5, 1908	Aug. 24, 1908	20	Mar. 9, 1909	214	99	73.0	85.1	857.25
Aug. 8, 1908	Aug. 28, 1908	21	Feb. 17, 1909	167	96	73.0	84.9	878.25
Aug. 14, 1908	Sept. 4, 1908	22	Feb. 5, 1909	144	96	75.0	83.4	908.50
Aug. 16, 1909	Sept. 8, 1909	24	Mar. 30–Apr. 27, 1910	193–221	110	77.0	89.38	1,112.75
Aug. 14, 1909	Sept. 3, 1909	21	Nov. 18, 1909–Jan. 25, 1910	76–144	110	77.0	89.51	976.25

The larva (Tables LXXI-LXXIII).—The greatest longevity of larvæ observed by us was 227 days. Engorgement has taken place as soon as the fourth day. As is shown in the last record in Table LXXII,

the longest period of engorgement observed was 14 days. In this case the larvæ were scratched off when between one-fourth and five-sixths engorged. Six of the 8 were engorged sufficiently to molt. The first lot recorded in the table did not attach readily and for this reason those ticks which did not take hold at first were allowed to remain in the bag. Thus the larvæ which dropped on the ninth day probably did not attach until the third day after application. In the third lot recorded in the table the squirrel escaped from the cage on the afternoon of the fifth day after the ticks were applied and was not put back until the next morning. There is little doubt that some larvæ dropped in the meantime.

TABLE LXXII.—*Engorgement of larvæ of Dermacentor parumapertus marginatus.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.											Total number dropped.
		1	2	3	4	5	6	7	8	9	10	14	
Aug. 7, 1908	Bovine	0	0	0	0	0	4	5	3	1	0	0	13
Aug. 26, 1908	.....do	0	0	0	0	7	2	0	0	0	0	0	9
Oct. 9, 1909	Squirrel	0	0	0	12	5	4	2	0	0	0	0	23
Nov. 4, 1909	Guinea pig	0	0	0	0	2	2	8	7	1	0	0	20
Mar. 11, 1910	.....do	0	0	0	0	0	2	0	2	0	2	0	6
Sept. 28, 1910	.....do	0	0	0	0	0	0	0	0	0	0	8	8

At a mean temperature of 87° F. molting occurred on the eighth day, an effective temperature of 350° F. having accumulated.

TABLE LXXIII.—*Molting of engorged larvæ of Dermacentor parumapertus marginatus.*

Date engorged larvæ dropped.	Host.	Number.	Engorged larvæ molted—days following dropping.																	Total number molted.	Temperature from dropping to date first tick molted.		
			8	9	10	11	12	13	14	15	16	19	20	21	23	24	26	39	47		Maximum.	Minimum.	Average daily mean.
1908.																					°F.	°F.	°F.
Aug. 12	Bovine	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	96	76	85.6
Aug. 13	.....do	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	96	77	86.8
Aug. 14	.....do	5	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	5	96	76.5	85.3
Aug. 15	.....do	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	96	76	84.8
Aug. 16	.....do	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	96	76	84.5
Aug. 31	.....do	2+	0	2	Others missing.														0	2	97.5	75	85.0
1909.																							
Oct. 13	Squirrel	12	0	0	0	0	0	0	0	4	8	0	0	0	0	0	0	0	0	12	87	51	67.83
Oct. 14	.....do	5	0	0	0	0	0	1	1	2	1	0	0	0	0	0	0	0	0	5	87	51	71.37
Oct. 15	.....do	5	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	4	87	51	70.92
Oct. 16	.....do	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	86	51	70.93
Nov 9	Guinea pig	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	79	41	64.95
Nov. 10	.....do	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	79	41	64.75
Nov. 11	.....do	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	5	79	34.5	63.55
Nov. 12	.....do	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	79	20	54.45
Nov. 13	.....do	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	79	32	61.35
1910.																							
Mar. 17	.....do	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	92	53	68.54
Mar. 19	.....do	2	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2	92	53	71.82
Oct. 12	.....do	8	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0	0	7	94	43.5	71.58
	Total	68+																		57			

The nymph (Table LXXIV).—The greatest longevity of nymphs observed by us was 175 days. This record was made on a lot of 7 nymphs which molted from larvæ October 27–31, 1910, and were kept on moist sand in the laboratory. In another lot of 22 nymphs which molted from larvæ October 27 to November 5, 1909, 2 were alive March 9, 1910, when they were put on a host, thus having lived at least 144 days. Three lots of unengorged or slightly engorged nymphs collected on rabbits lived from 30 to 100 days.

Attempts to get nymphs to attach to a bovine failed and in our early experiments no attachments were secured when the nymphs were put on tame rabbits and guinea pigs. In 1910, two attempts to attach nymphs to a fox squirrel failed, and similar results were experienced in two of six tests on guinea pigs. In one instance a single nymph attached readily to a guinea pig, and 2 nymphs put on a rabbit attached and engorged readily.

The shortest period of engorgement observed was 4 days and the longest 25 days.

TABLE LXXIV.—*Engorgement of nymphs of Dermacentor parumapertus marginatus.*

Date nymphs applied.	Host.	Number.	Nymphs dropped engorged—days following application.							Total number dropped.
			4	8	9	10	12	19	25	
Dec. 10, 1909	Guinea pig	9	0	1	0	1	1	1	0	4
Feb. 3, 1910	do	1	0	0	0	0	0	0	1	1
May 25, 1910	Rabbit	2	1	0	1	0	0	0	0	2

Nymphs which dropped in August molted in 21 days when the mean temperature was 88.25° F. One nymph which dropped December 19, 1909, molted 123 days later. This was the longest molting period observed. During this period the mean temperature was 60.24° F. The mean temperature has a decided effect on the length of the molting period. The molting periods of those nymphs which become males and those which become females are about the same. A total effective temperature of 641° F. appears to be required to produce this molt.

The adult (Table LXXV).—The number of individuals of each sex was practically the same in the adults which we observed to molt from nymphs. The greatest longevity recorded occurred in a lot of 11 males and 4 females which were collected on rabbits on April 21–25, 1910. On August 18, 1910, a male and a female were alive, but these died before September 26, 1910, having lived between 115 and 158 days. Of a lot containing 21 males and 8 females which molted between May 12 and May 30, 1910, 2 males and 2 females lived between 80 and 137 days. A number of other lots of collected individuals lived from 25 to 72 days. The longevity of the sexes is practically the same.

Unengorged or slightly engorged males and females taken from rabbits have readily attached when placed upon a bovine host.

They have been found to mate within a day or two and to continue in this relation for a number of days or until the females dropped. As many as three-fourths of the individuals collected in western Texas were found paired. In one instance a male was found paired with a female of *Dermacentor variabilis*. After the dropping of the female with which it had mated, one male was observed mated with a female of *M. annulatus*. It remained in this relation until it was removed from the host a week later.

About 30 lots of this species have been collected by agents of the bureau. In only two instances were any engorged females found. Engorgement of females that were removed from rabbits took place upon bovine hosts in 12 days. A female which was placed upon a tame rabbit with a male on May 25, 1910, did not show any sign of engorging until 10 days later, when it was observed in copulation. Engorgement began on the third day following mating, but the date of dropping of this individual was not recorded. The females, during engorgement, excrete large quantities of material which when dry resembles coagulated blood. This frequently incrusts the male which is beneath the female, thus rendering him helpless and sometimes actually killing him.

The ear of the rabbit, both inside and outside, appears to be preferred as a place for attachment. The large number of males that have been taken from rabbits is sufficient evidence that they remain upon the host for a long period after the females have dropped.

TABLE LXXV.—*Engorgement of females of Dermacentor parumapertus marginatus.*

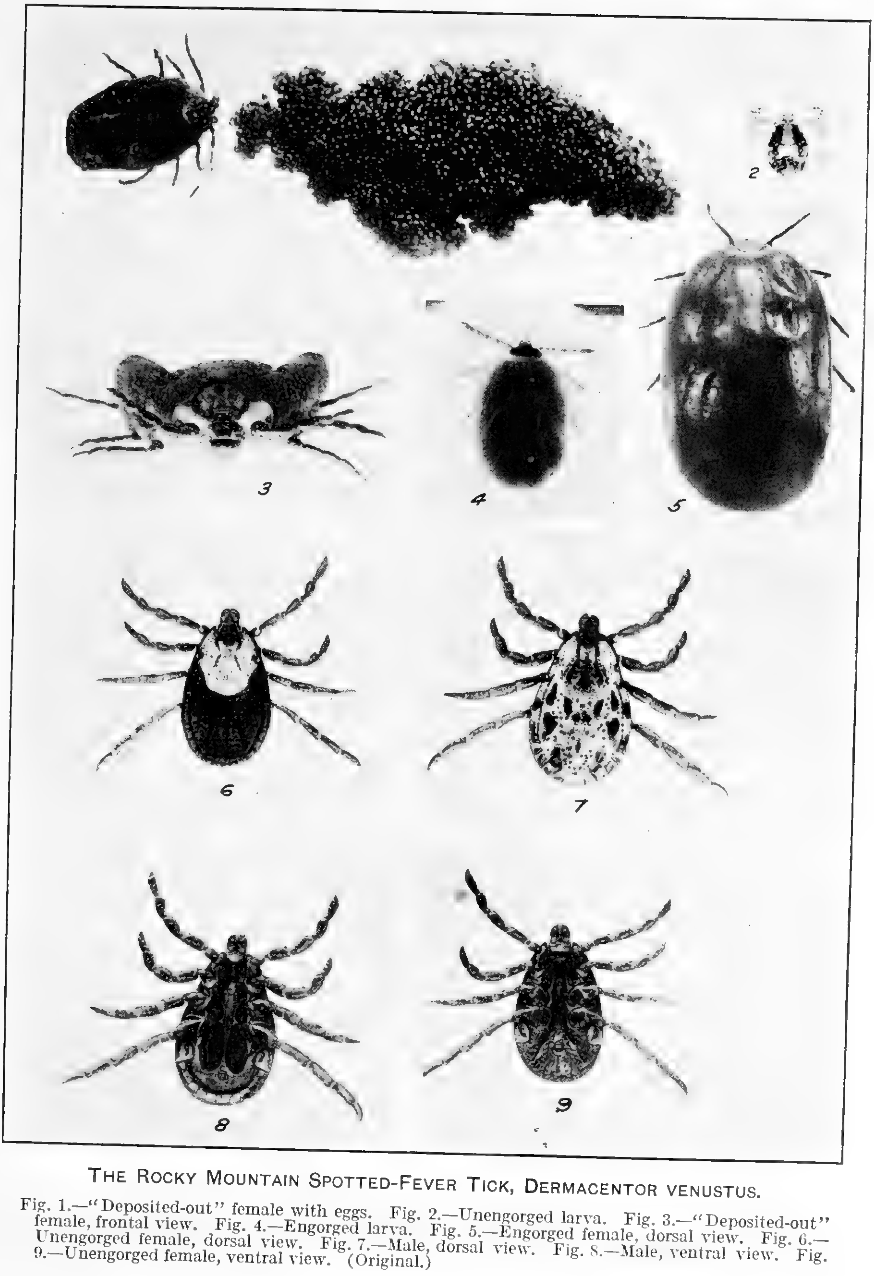
Adults applied.	Host.	Females dropped engorged.	Period of attachment.	Size engorged.
			Days.	
June 8, 1908	Bovine	June 21, 1908	13	10 by 7 by 4 mm.
June 29, 1908	do	July 11, 1908	12	11 by 8.5 by 5 mm.
Do	do	July 14, 1908	15	12.5 by 9 by 6.5 mm.
July 7, 1908	do	July 19, 1908	12	12 by 8.5 by 6 mm.
Do	do	July 21, 1908	14	11 by 7.5 by 4 mm.
Do	do	July 25, 1908	18	10 by 7 by 5 mm.
Do	do	Aug. 2, 1908	26	10 by 7 by 3.5 mm.
Aug. 27, 1908	do	Sept. 5, 1908	(Sloughed off.) 9	10 by 7 by 4.5 mm.
June 25, 1909	do	July 7, 1909	12	

LIFE CYCLE.

Larvæ may live as long as 227 days; they engorge as soon as 4 days after application and may molt in 8 days after dropping, a total effective temperature of 350° F. being required.

Nymphs may live as long as 175 days; they may engorge in 4 days after application and molt as soon as 21 days after dropping, a total effective temperature of 641° F. being required.

Adults have been found to live for more than 115 days. Mating takes place on the host. Females may engorge as soon as 12 days after being put on a host; they may begin oviposition as soon as 5 days after dropping and deposit as many as 4,660 eggs. Deposition may continue for 26 days. Embryonic development may be com-



THE ROCKY MOUNTAIN SPOTTED-FEVER TICK, DERMACENTOR VENUSTUS.

Fig. 1.—"Deposited-out" female with eggs. Fig. 2.—Unengorged larva. Fig. 3.—"Deposited-out" female, frontal view. Fig. 4.—Engorged larva. Fig. 5.—Engorged female, dorsal view. Fig. 6.—Unengorged female, dorsal view. Fig. 7.—Male, dorsal view. Fig. 8.—Male, ventral view. Fig. 9.—Unengorged female, ventral view. (Original.)

pleted in 20 days, a total effective temperature of 850° F. or more being required.

ECONOMIC IMPORTANCE.

This variety of *Dermacentor parumapertus* has not been taken on any other host than the rabbit; hence it is of no importance economically.

NATURAL CONTROL.

Rabbits kept in cages have been observed to scratch off and devour fully engorged females. It seems probable therefore that some of these ticks suffer the same fate in nature.

To test the effect of heat upon eggs of this species, a bunch of freshly deposited eggs was placed on the ground in the sun from 3.55 p. m. until sunset. When the eggs were put out the atmospheric temperature was 110° F. and the soil surface temperature was 133° F. The eggs were somewhat shriveled when taken in and later they dried up completely. They showed no sign of embryonic development, while a check lot hatched in 9 days. There is little doubt that heat and dryness are important in controlling the abundance of this species.

One of two nymphs collected on a rabbit at Green Valley, Cal., on June 11,1909, was found to be parasitized by *Hunterellus hookeri*. This is the same species which acts as a parasite of the nymphs of *Rhipicephalus sanguineus*.

THE ROCKY MOUNTAIN SPOTTED-FEVER TICK.

Dermacentor venustus Banks.

The common name of this species is taken from the fact that it is the transmitter of the disease of man known as Rocky Mountain spotted fever.

DESCRIPTIVE.

Adult (Pl. XIV, figs. 1, 3, 5–9).—Males from 2.1 by 1.5 mm. to 6 by 3.7 by 1.4 mm. Females, unengorged, from 3.1 by 1.8 mm. to 5.1 by 3 mm.; engorged, from 13.8 by 10 by 6.4 mm. to 16.5 by 11.4 by 6.9 mm. Male reddish brown; scutum with an extensive pattern of white lines; usually but little white on the middle posterior region; legs slightly lighter than scutum; joints tipped with white; female with scutum mostly covered with white; abdomen reddish brown; legs as in the male.

Nymph.—Unengorged, from 1.36 by 0.72 mm. to 1.54 by 0.8 mm.; engorged, from 3 by 2.1 by 1.3 mm. to 4.8 by 3.3 by 2 mm. Color, unengorged, reddish brown; engorged, dark bluish gray. Capitulum 0.336 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.550 mm. long by 0.554 mm. wide.

Larva (Pl. XIV, figs. 2, 4).—Unengorged, from 0.631 by 0.387 mm. to 0.703 by 0.445 mm.; engorged, from 1.28 by 0.76 mm. to 1.43 by 0.85 mm. Color, unengorged, yellowish brown; scutum darker toward posterior end; engorged, slate-blue. Capitulum 0.139 mm.

long (from tip of palpi to base of emargination of scutum); scutum 0.241 mm. long by 0.350 mm. wide.

Egg.—The average size of 10 eggs measured was 0.645 by 0.460 mm.; light brown, shining, smooth.

HOST RELATIONSHIP.

The host of the type of this species is not known. Most of the information herein presented regarding the host relationship of the species was obtained in the Bitter Root Valley of Montana. The work there was conducted under the general supervision of Mr. W. D. Hunter, but under the immediate direction of Prof. R. A. Cooley. Mr. W. V. King, of the Bureau of Entomology, and Mr. C. Birdseye, of the Bureau of Biological Survey, spent the spring and summer, and Mr. A. H. Howell, of the Biological Survey, a portion of the spring of 1910 in the center of the area where Rocky Mountain spotted fever occurs in its most virulent form. Messrs. King and Birdseye continued this investigation throughout 1911 in the same locality. To these men, who exposed themselves to the dangers of infection in order to collect information regarding this tick and its hosts, we are greatly indebted. In order to identify with certainty the species of ticks collected, the immature stages were sent to the laboratory at Dallas, Tex., and reared to adult and determined. It has been found that practically all of the small mammals act as hosts for the larvæ and nymphs, while the adult stages are seldom found on other than the large domestic animals. Horses and cattle appear to be by far the preferred hosts. Among other domestic animals upon which adults have been found are sheep, mule, ass, dog, hog, goat, and cat (probably unattached). The principal wild mammals found to act as hosts for this stage are the mountain goat, brown bear, coyote, woodchuck, rabbit, wild cat, and badger. The last three appear to be rarely attacked by the adults of this species. The immature stages have been taken on the following hosts which are arranged approximately according to their relative importance: Ground squirrel (*Citellus columbianus*), pine squirrel (*Sciurus hudsonicus richardsoni*), chipmunks (*Eutamias luteiventris, Eutamias quadrivittatus umbrinus*), rock squirrel (*Callospermophilus lateralis cinerascens*), woodchuck (*Marmota flaviventer*), rabbits (*Sylvilagus nuttalli* and *Lepus bairdi*), wood rat (*Neotoma cinerea*), gray meadow mouse (*Microtus nanus canescens*), pika (*Ochotona princeps*), white-footed mouse (*Peromyscus maniculatus artemisiæ*), large meadow mouse (*Microtus modestus*), jumping mouse (*Zapus princeps*), and pocket gopher (*Thomomys fuscus*).

Dr. H. T. Ricketts and Prof. R. A. Cooley have given a considerable amount of information on the host relationship of this species. Dr. Ricketts states that in Idaho this tick was found on the snowshoe rabbit (*Lepus bairdi*) in considerable numbers in all stages of

development. It seems very probable, in the light of our recent investigation, that this note applies to the rabbit tick, *Hæmaphysalis leporis-palustris*. Additional information on the host relationships of this species is given by Hunter and Bishopp (1911b).

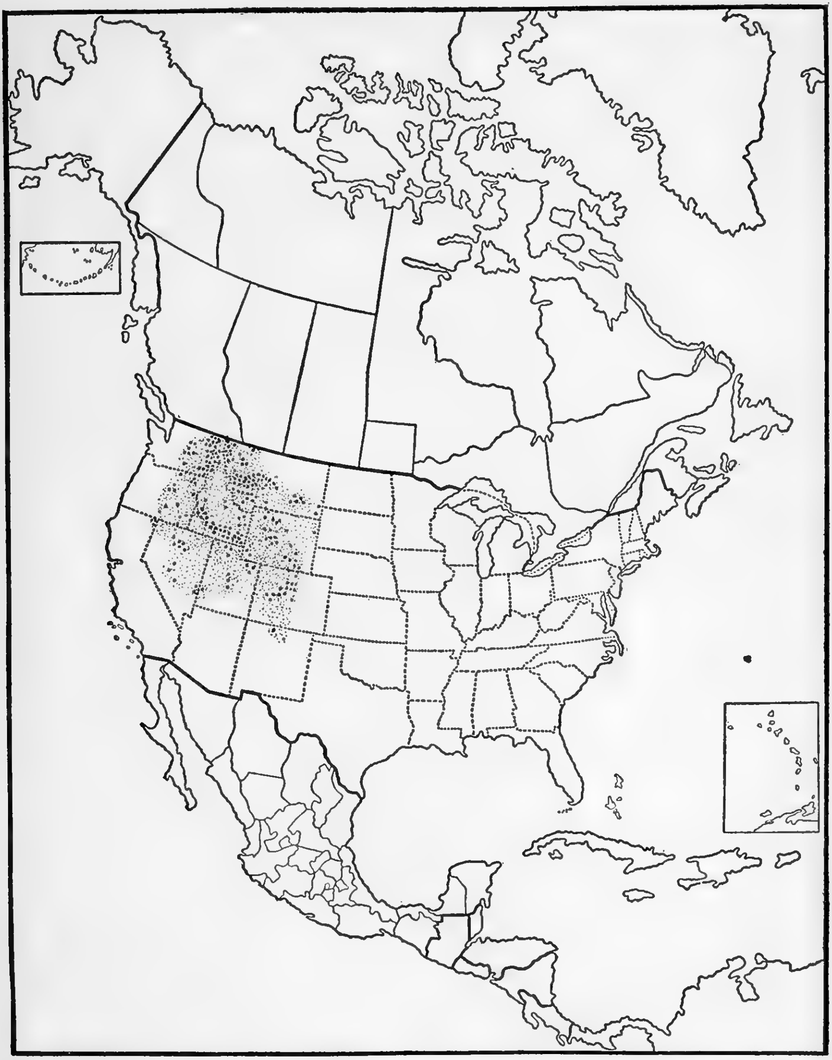


FIG. 14.—The Rocky Mountain spotted-fever tick, *Dermacentor venustus:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the tick. (Original.)

We have been able to engorge all the stages of the Rocky Mountain spotted-fever tick on the guinea pig, tame rabbit, and bovine, and the adults have been engorged on the goat.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 14.)

The type locality of this species is Soldier, Idaho. The distribution of this tick has been rather accurately determined by the Bureau of Entomology working in cooperation with Prof. R. A. Cooley and numerous correspondents throughout the Western States. The tick has been found to occur from British Columbia southward to northern New Mexico and from the foothills of the Rocky Mountains in Colorado to the base of the Cascade Range in Oregon and California. It is very abundant in western Montana, and throughout Idaho, eastern Washington, and Oregon, northern Utah, western Wyoming, and northwestern Colorado. A detailed statement regarding the distribution of this species has been published (Bishopp, 1911a).

LIFE HISTORY.

Observations on the biology of this tick have been published by Ricketts (1906, 1907, 1908) and by Cooley (1909, 1911).

The egg (Table LXXVI).—The preoviposition period of this species varies from 5 to 17 days. One partially engorged female which was picked from a host March 24, 1910, had a preoviposition period of 25 days. The temperature experienced by these ticks can not be given accurately, as the ticks were collected in Montana and mailed to the laboratory at Dallas. Females which dropped from hosts at the Dallas laboratory showed a variation of from 6 to 14 days in their preoviposition periods. The shorter period was recorded on specimens kept at 66° F. and the longer on specimens kept at 79° F. However, preoviposition periods of 7 days were observed when the mean temperature was about 80° F. and when the mean temperature was 68° F. preoviposition periods as long as 14 days were observed. The period of deposition varied from 15 to 32 days. The maximum number of eggs deposited by a female was 7,396; the average of 11 was 5,421.8. The individual which deposited the maximum number of eggs measured 16 by 11.5 by 6.1 mm. before deposition was begun. The number of eggs deposited by an individual is governed largely by its size.

Females which were removed from a host when about one-fourth engorged have been found to deposit fertile eggs. Three females which measured 8 by 5.5 by 2 mm., 8.3 by 5.3 by 2 mm., and 8.5 by 5.5 by 2 mm., began depositing on the fourteenth, tenth, and twelfth days after being removed from the host and deposited 211, 1,019, and 636 eggs, respectively.

The minimum incubation period recorded was 16 days. This occurred in the case of eggs deposited June 13, 1908, which experienced a mean temperature of 81.4° F. A total effective temperature of 614.75° F. was accumulated during this period. Ricketts states (1909a, p. 100) that in Montana eggs deposited in July hatch in from

30 to 50 days after they are deposited. Records made by Mr. W. V. King show the incubation period to vary from 34 to 51 days in the Bitter Root Valley in Montana.

TABLE LXXVI.—*Preoviposition, incubation, and larval longevity of Dermacentor venustus.*

Date engorged female dropped.	Deposition began.	Preoviposition period.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
							Maximum.	Minimum.	Average daily mean.	Total effective temperature.
1908.	1908.	*Days.*	1908.	*Days.*			*° F.*	*° F.*	*° F.*	*° F.*
	June 6		June 24	19			91.5	69	80.8	718.25
	June 7		do	18			91.5	69	80.8	680.5
	June 13		June 28	16			91.5	71	81.4	614.75
	June 15		July 1	17			90	71	80.8	641.75
1909.	1909.		1909.							
[1] July 1	Before July 14.	13	July 31	18+	Before Sept. 15.	46–				
[1] June 11	June 27	16	July 15	19	Aug. 26–Sept. 15.	42–62	102	47	91.8	917
1910.	1910.		1910.							
[1] Mar. 28	Apr. 7	10	May 10	34	July 19–Aug. 5.	70–87	91	43	70.49	744.66
Apr. 7	Apr. 17	10	May 19	33	Before July 19.	61–	95	51	74.6	979.6
Apr. 12	Apr. 18	6	do	32	July 19–Aug. 5.	61–78	91	43	70.33	874.56
Do	Apr. 22	10	May 25	34	Aug. 8	75	91	43	74.8	1,081.2
[1] Apr. 13	Apr. 20	7	do	36	Aug. 5–20	72–87	91	43	71.78	1,036.08
Apr. 26	May 2	6	May 31	30	July 20–Aug. 5.	50–66	91	59	71.66	859.8
[1] May 1	May 10	9	June 6	28	July 21–Aug. 5.	45–60	100	59	77.02	952.56
[1] May 14	May 23	9	June 12	21	Aug. 25–31	74–80	100	60	79.64	769.44
[1] June 4	June 13	9	June 29	17	Sept. 29	92	97	69	84.37	703.29
[1] June 8	do	5	July 1	19	Aug. 25–31	55–61	97	69	84.59	790.21
[1] July 16	July 25	9	Before Aug. 10.	17–	Sept. 24–Oct. 5.	45–56	104	79	90.19	755.23
1911.	1911.		1911.							
Mar. 27	Apr. 4	8	May 14	41			89	52	71.7	1,176.7

[1] This tick was picked from the host.

The larva (Tables LXXVI–LXXVIII).—The longest time between the beginning of hatching of a lot of eggs deposited by a single female and the death of the last larva was 92 days. In this case the eggs and larvæ were kept on moist sand in a tube in the laboratory. Hatching began on June 29, 1910, and the last larva died on September 29. In the majority of cases in a series of over 200 observations the last larva died within 85 days from the time the first eggs in the lot hatched. In a number of lots of eggs separated from the parent female the day they were deposited the larvæ all died within 2 months after hatching, even though kept under the most favorable conditions. In a number of instances larvæ which hatched the latter part of July and early in August all died within a month. Cooley's experiments in Montana (1909, p. 102), as well as tests made by W. V. King in that State, indicate that the longevity of larvæ in Montana is about the same as that observed by us at Dallas, Tex.

On account of the fact that the period of deposition is frequently longer than the incubation period, in warm weather the larvæ begin

to hatch from the first eggs deposited some time before deposition is complete.

Ordinarily larvæ attach within a very short time after they are applied to a host. However, we have observed them to remain unattached for three days when kept in close proximity to a host. The majority of the larvæ attach around the head and ears of the hosts. They are, however, frequently found on the back, especially between the shoulders. Larvæ when removed from a host when slightly engorged were found to attach to another host several days or even weeks later.

In a number of instances larvæ which had awaited a host for two months were found to attach when placed on a host, but many, and in some cases all, died without engorging owing to their weakened condition.

The shortest period required for the engorgement of larvæ was two days. The greatest number drop from the host on the third, fourth, and fifth days after attachment. In two cases larvæ remained on the host for 8 days.

TABLE LXXVII.—*Engorgement of larvæ of Dermacentor venustus.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.								Total number dropped.
		1	2	3	4	5	6	7	8	
1908.										
March 30	Bovine	0	0	0	1	2	0	0	0	3
April 2	do	0	0	23	27	17	13	3	1	84
May 13	do	0	0	0	15	10	0	0	0	25
July 8	do	0	0	2	3	0	0	0	0	5
July 12	do	0	0	76	64	12	4	0	0	156
1909.										
July 28	Guinea pig	0	0	0	0	6	2	2	0	10
July 30	do	0	0	0	0	6	5	0	0	11
Do	Bovine	0	0	0	2	1	0	0	0	3
Aug. 2	Rabbit	0	0	0	0	3	0	0	0	3
Aug. 4	Guinea pig	0	0	0	0	2	0	0	0	2
Do	Bovine	0	0	0	1	2	0	0	0	3
Aug. 17	do	0	0	0	1	0	0	0	0	1
Do	Guinea pig	0	0	0	0	0	1	0	0	1
Aug. 25	do	0	0	0	0	23	23	2	0	48
Aug. 27	do	0	13	26	58	56	23	5	0	181

When the mean temperature was about 83° F. larvæ were found to become quiescent in from 24 to 60 hours after dropping. Immediately after becoming quiescent the tick begins to take on a light color at the anterior end.

Larvæ which dropped September 1, 1909, began molting on the sixth day thereafter. This was the shortest molting period observed. The mean temperature during the period was 88.29° F. and a total effective temperature of 272° F. was accumulated. The longest period from dropping to molting observed by us was 19 days. The mean temperature during this period was 70.5° F. The effect of temperature on the length of the molting period is marked. When the mean temperature was about 70° F. molting began between

the thirteenth and sixteenth days; when the mean temperature was about 77° F. molting began between the eighth and tenth days, and when the temperature was about 88° F. molting began between the sixth and eighth days. Cooley reports (1909, p. 101) that larvæ which dropped during the latter part of July at indoor temperature at Bozeman, Mont., commenced to molt in as soon as 13 days thereafter, and that the majority molted within three weeks. We have found that larvæ will often molt if removed from the host when only slightly over one-half engorged. The molting period of specimens which are not fully engorged is noticeably longer than in replete individuals.

The last six lots, the molting of which is recorded in the accompanying table, contained individuals from one-half to almost fully engorged. The length of the molting period was undoubtedly lengthened on account of the ticks having been picked from hosts before they were replete. The temperatures given with these lots are those recorded at the Dallas laboratory from the time the ticks were collected in Montana until molting began. The specimens undoubtedly experienced lower temperatures than those recorded during the few days prior to their receipt at Dallas.

TABLE LXXVIII.—*Molting of engorged larvæ of Dermacentor venustus.*

Date engorged larvæ dropped.	Host.	Number.	Engorged larvæ molted—days following dropping.														Total number molted.	Temperature from dropping to date first tick molted.		
			6	7	8	9	10	11	12	13	14	15	16	17	18	19		Maximum.	Minimum.	Average daily mean.
1908.																		°F.	°F.	°F.
Apr. 4	Bovine	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	85	54	70
Apr. 5	.....do	23	0	0	0	0	0	0	0	0	0	2	2	7	2	1	14	85	58	70.5
Apr. 6	.....do	27	0	0	0	0	0	0	0	1	5	11	6	2	0	0	25	85	58	70.4
Apr. 7	.....do	17	0	0	0	0	0	0	0	1	7	2	2	2	1	0	15	85	58	70.3
Apr. 8	.....do	13	0	0	0	0	0	0	0	0	5	8	0	0	0	0	13	80	58	70.3
May 17	.....do	15	0	0	0	0	1	9	2	1	0	0	0	0	0	0	13	87	68	77.4
May 18	.....do	10	0	0	0	1	6	3	0	0	0	0	0	0	0	0	10	87	68	77.6
July 15	.....do	76	0	0	0	2	26	31	0	0	0	0	0	0	0	0	59	95	76.5	84.3
July 16	.....do	43	0	0	4	17	20	2	0	0	0	0	0	0	0	0	43	95	76.5	84.4
July 17	.....do	9	0	0	0	5	1	1	0	0	0	0	0	0	0	0	7	95	76	83.9
1909.																				
July 19	.....do	3	0	0	2	0	1	...	...	...	...	...	...	...	...	...	3	97	79.5	89.72
Aug. 2	Guinea pig	6	0	1	1	2	0	1	0	1	0	0	0	0	...	...	6	102	78.5	88.57
Aug. 6	.....do	7	0	3	0	0	4	...	...	...	...	...	...	...	...	...	7	96	78	85.75
Aug. 29	.....do	36	0	(1)	22	5	5	1	0	0	0	0	0	0	0	0	33	98	80	88.5
Aug. 30	.....do	49	(1)	8	21	7	2	0	0	0	0	0	0	0	0	0	38	98	80	88.37
Aug. 31	.....do	60	0	10	30	12	0	0	0	0	0	0	0	0	0	0	52	98	78.5	88.18
Sept. 1	.....do	56	2	14	27	5	0	0	0	0	0	0	0	0	0	0	48	98	78.5	88.29
Do...	Rabbit	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	98	78.5	88.32
Sept. 2	Guinea pig	25	0	12	8	0	0	0	0	0	0	0	0	0	0	0	20	99	78.5	88.55
1910.																				
July 4[2]	Ground squirrel	17	0	0	0	0	0	1	0	0	0	12	0	1	0	0	14	97	73	85.5
July 14[2]	.....do	23	0	0	0	0	0	17	0	3	0	0	0	0	0	0	20	103.5	73	88.25
July 22[2]	Chipmunk	20	0	0	0	0	0	0	17	0	0	0	0	0	0	0	17	104	80	90.5
July 29[2]	Ground squirrel	14	0	0	0	0	0	0	0	6	2	6	...	...	...	...	14	104	79	84.48
Aug. 10[2]	Pine squirrel	29	0	0	0	0	7	(1)	11	1	...	...	...	...	...	...	19	104.5	82	92.1
Aug. 14[2]	Wood rat	3	0	0	0	0	0	0	1	1	0	1	...	...	...	...	3	104.5	73	90.69
	Total	586	...	...	...	...	...	...	...	...	...	...	...	...	...	...	496	.....	.....	.....

[1] The larvæ which molted on this day are included with those recorded on the following day.
[2] These ticks were picked from native hosts in Montana and varied from one-half to fully engorged.

The nymph (Tables LXXIX–LXXX).—The greatest nymphal longevity observed by us occurred in the case of a lot of 119 nymphs which molted from larvæ September 5–10, 1909. These nymphs, as also all other lots here recorded, were kept in the laboratory in tubes on moist sand. During the fall months 21 nymphs were removed from this lot and put on hosts, and during March, 1910, 16 were applied to hosts, 10 of these being applied March 18. On April 20, 1910, only one specimen was alive. This individual died before June 3, 1910. Thus it is seen that during the winter months a considerable number of nymphs lived for at least 189 days, at which time they were applied to a host and became engorged, and one nymph lived between 252 and 271 days. It seems certain that had none of this lot been put on hosts, some individuals would have lived considerably longer.[1] In a lot of 12 or more nymphs which molted from larvæ April 19–21, 1908, 3 individuals were alive 178 days later. The last specimen died October 21, 1908, having lived between 183 and 185 days. One individual in a lot of 7 or more specimens which became nymphs July 24–25, 1908, lived between 137 and 145 days. All specimens in two other lots of about 7 individuals each were found to have died between 56 and 75 days after they transformed to nymphs on July 25, 1908.

Among nymphs which were collected from hosts when slightly to one-third engorged, a longevity of from 47 to 122 days was recorded. The longest period—namely, 122 days—was observed in the case of one individual in a lot of 59 unengorged or very slightly engorged nymphs which were collected on a ground squirrel on April 12, 1910, at Florence, Mont., by Mr. W. V. King.

Nymphs kept in tubes in the laboratory at Dallas were found to be active most of the time at all seasons of the year while awaiting hosts. Occasionally a few individuals were seen to be grouped together and remaining quiet. These, however, were readily disturbed.

In most instances nymphs have been found to attach almost immediately after being placed on a host. Individuals have been found to attach to a host and become engorged after having been picked from another host when as much as one-fourth engorged.

Engorged nymphs have dropped as soon as the fourth day following attachment, the last leaving the host on the ninth day. This period is the same as that recorded by Ricketts (1908, p. 101). The engorgement period of nymphs which were collected on hosts when slightly engorged appears to be somewhat shorter than in the case of those nymphs which have not before been attached to a host. In two instances these slightly engorged nymphs have been found to

[1] Since the above was written a record of nymphs living over 300 days has been made by us.

drop fully engorged on the third day after application. The longest period required for engorgement, of these reattached nymphs, was 6 days.

TABLE LXXIX.—*Engorgement of nymphs of Dermacentor venustus.*

Date nymphs applied.	Host.	Number.	Nymphs dropped—days following application.							Total number dropped.
			3	4	5	6	7	8	9	
1908.										
Apr. 1	Bovine	+34	......	2	17	13	2	......	......	34
May 14	do	+16	......	2	6	3	4	1	......	16
1909.										
Aug. 9 [1]	Rabbit	10	1	5	3	......	......	......	......	9
Aug. 13	Guinea pig	6	......	1	1	......	......	......	......	2
Sept. 10	Rabbit	9	......	2	5	......	......	......	......	7
Oct. 5	Bovine	7	......	......	......	1	......	2	......	3
1910.										
Mar. 18	Guinea pig	10	......	......	2	1	2	......	......	5
Apr. 29 [1]	Squirrel	10	......	......	2	5	......	......	......	7
May 17 [1]	Guinea pig	3	......	......	......	......	2	......	1	3
May 24	Bovine	8	......	......	......	4	......	......	......	4
July 27	Rabbit	10	......	......	7	1	......	......	......	8
Aug. 9 [1]	do	9	......	5	3	......	......	......	......	8
Aug. 13	do	13	......	......	8	2	1	......	......	11
Aug. 15 [1]	Guinea pig	30	7	12	3	......	......	......	......	22
Aug. 19	Rabbit	14	......	5	1	......	......	......	1	7
Aug. 25 [1]	Guinea pig	9	......	......	4	4	......	......	......	8
	Total	+198	......	......	......	......	......	......	......	154

[1] These individuals were collected on hosts when unengorged or slightly engorged and reattached on this date.

In our observations engorged nymphs molted in two instances as soon as the eleventh day after dropping. The first instance occurred in a lot of ticks which dropped August 6, 1908. The mean temperature during this period was 87° F., 485° F. of effective temperature having been required for this transformation. Most of the ticks from this same lot, which dropped on the same day, molted on the fourteenth, fifteenth, and sixteenth days. The second case, when a molting period of 11 days was observed, occurred with a nymph which dropped July 21, 1910. The mean temperature during this period was 89.5° F. and the total effective temperature was 511° F. There is a great variation in the periods required by this species for molting. Thus of 3 engorged nymphs which dropped May 20, 1908, 2 molted to females on the seventeenth and eighteenth days, while the third did not molt to adult until the forty-ninth day after dropping. A still more marked variation in the molting periods of a group of ticks was observed in a lot of 3 nymphs which dropped October 3, 1909. Two of these molted on the eighteenth and nineteenth days after dropping, while the third did not transform until March 22, 1910, or 170 days after dropping. Both of these lots were kept under identically the same conditions and all appeared to be fully engorged. In the second instance the molting of the last nymph

was undoubtedly delayed by the approach of cold weather, but the first instance, as well as other similar cases of variation in molting periods, are difficult to explain. Cooley (1909, p. 101) found nymphs which dropped August 12 to commence molting in 42 days, while others required 47 days. Ricketts states (1908, p. 102) that the period required for molting varies from 1 to 3 months, according to the temperature.

After dropping, the nymphs remain rather active for from 3 to several days or even weeks, depending upon temperature and state of engorgement. When it is cool the activity continues for a longer period than during hot weather and partial engorgement has the same effect. The nymphs usually become inactive gradually and within a few days after complete quiescence the area around the anterior end and the antero-lateral borders begins to become white. Dr. Ricketts has found the engorged nymphs to remain active in Montana during July and August for from 2 to 4 weeks, while if placed in a refrigerator they remained active for as long as 3 months. The sexes can often be distinguished several days before molting occurs by the appearance of the color pattern of the adult showing through the skin. In one case the female shields were easily seen 6 days before molting took place. Some days prior to molting the surface of the body of the engorged nymphs frequently becomes dotted with small drops of a yellowish transparent fluid exudate.

Molting is accomplished in the same manner as observed in other species of Dermacentor. The old skin first becomes free from the body at the anterior end, then splitting occurs on each side just above the third pair of legs. Later this splitting extends forward on each side to the lateral angles of the scutum, where the splitting follows the edges of the shield and the two fissures meet at the tip of the scutum. In many cases the force exerted by the tick causes the splitting to extend back around the ventro-lateral margin so that the skin is broken in two. In other cases the lateral fissures extend backward along the dorso-lateral border to the second festoon grooves where they follow these grooves toward the venter, the dorsal end of the skin forming a hinge which allows the escape of the tick.

The length of the molting period of nymphs which transform to males and of those which become females is about the same.

TABLE LXXX.—*Molting of engorged nymphs of Dermacentor venustus.*

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.																		
			11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	29	30	31
1908.																					
May 18	Bovine	2						1♂	1♀												
May 19	do	6							1♂	1♂ 1♀											
May 20	do	4							1♀	1♀											
May 21	do	4							1♂												
Aug. 6	do	17	1♀			4♂	3♂ 2♀	4♂ 2♀													
Aug. 7	do	13				1♂ 1♀	2♂ 1♀	6♂	1♂												
1909.																					
Aug. 18	Guinea pig	1				1♂															
Sept. 15	Rabbit	5										1♂ 2♀	2♂								
Oct. 3	Bovine	3								1♂	1♂										
1910.																					
Mar. 10	Rabbit	1																			
Mar. 23	Guinea pig	2																			
Apr. 14[1]	Ground squirrel	13																			
May 5	Fox squirrel	5																			
May 16[1]	Ground squirrel	25																	1♀	2♂ 2♀	2♂ 1♀
May 30	Bovine	3													1♂		1♀	1♀			
June 13[1]	Ground squirrel	16												3♂ 2♀	2♂ 5♀	1♂					
July 21	Guinea pig	1	1♂																		
July 26[1]	Ground squirrel	10										1♂ 5♀	1♂ 1♀			1♀					
July 29[1]	Woodchuck	15									1♀	1♂ 2♀	2♀	4♀		1♀					
Aug. 1	Rabbit	6			1♂	1♂ 1♀	2♂														
Aug. 11	Guinea pig	3		2♀		1♂															
Aug. 18	Rabbit	7		1♂			2♀			1♂ 3♀											
Do.	Guinea pig	7			2♂ 2♀	2♀	1♀														
Aug. 19	do	12		2♀	2♂ 1♀	3♂ 3♀		1♀													
Aug. 30	do	6			1♂ 1♀	1♂ 1♀	1♂	1♂													
Sept. 28	Squirrel	1									1♀										
	Total	188																			

[1] These nymphs were collected on native hosts in Montana when from one-half to fully engorged.

TABLE LXXX.—*Molting of engorged nymphs of Dermacentor venustus*—Continued.

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.														Number molted.			Temperature from dropping to date first tick molted.		
			32	33	34	35	37	40	41	42	43	46	49	61	71	170	Male.	Female.	Total.	Maximum.	Minimum.	Average daily mean.
1908.																				° F.	° F.	° F.
May 18	Bovine	2															1	1	2	88.5	68.	78.6
May 19	do	6									1♀						2	2	4	88.5	68	79
May 20	do	4											1♀				0	3	3	88.5	68	79.1
May 21	do	4					1♀		1♀								1	2	3	89	68	79.2
Aug. 6	do	17															11	5	16	99	73	87.1
Aug. 7	do	13															10	2	12	99	73	86.5
1909.																						
Aug. 18	Guinea pig	1															1	0	1	103	77	88.52
Sept. 15	Rabbit	5															3	2	5	95.5	56	77.45
Oct. 3	Bovine	3														1♂	3	0	3	92.5	52.5	73.25
1910.																						
Mar. 10	Rabbit	1													1♂		1	0	1	92	43	70.55
Mar. 23	Guinea pig	2								1♀				1♂			1	1	2	89	43	70.80
Apr. 14[1]	Ground squirrel	13						1♀	2♀	1♀	1♂ 2♀	2♂ 2♀					3	8	11	91	43	70.86
May 5	Fox squirrel	5	1♀	1♂	1♂ 1♀												2	2	4	100	59	76.27
May 16[1]	Ground squirrel	25	5♂ 6♀			1♂ 2♀											10	12	22	100	60	81.69
May 30	Bovine	3															1	2	3	100	66	86.98
June 13[1]	Ground squirrel	16															6	7	13	98	69.5	90.63
July 21	Guinea pig	1															1	0	1	104	77.5	89.50
July 26[1]	Ground squirrel	10	1♂														3	7	10	104	79	90.80
July 29[1]	Woodchuck	15															1	10	11	104	79	90.07
Aug. 1	Rabbit	6															4	1	5	103	79	91.27
Aug. 11	Guinea pig	3															1	2	3	104.5	81.5	92.54
Aug. 18	Rabbit	7									1♂						2	5	7	104.5	73	88.96
Do	Guinea pig	7															2	5	7	104.5	73	88.94
Aug. 19	do	12															5	7	12	104.5	73	88.85
Aug. 30	do	6															4	2	6	98	72.5	85.62
Sept. 28	Squirrel	1															0	1	1	91	54.5	77.68
	Total	188															79	89	168			

[1] These nymphs were collected on native hosts in Montana when from one-half to fully engorged.

The adult (Table LXXXI).—Of 355 adults, the sex of which was determined when they molted from nymphs, 172, or 48.5 per cent, were males. Immediately after molting both sexes are rather plump; the voiding of numerous pellets of white excrement begins almost immediately, and within a few days the thickness of the ticks is much reduced. The voiding of excrement continues for some time, but the amount is greatly decreased after the first few days following molting.

Partial feeding in the nymphal stage has a marked effect on the resultant adults. The size is frequently reduced by more than one-half, the color pattern is often very weak or does not appear at all, and certain structures are affected.

The longevity of the adults of this species is remarkably great. One male in a lot which molted to adults in June, 1908, lived between 188 and 197 days. Three lots of ticks which molted between August

22 and August 25, 1908, lived between 250 and 290 days. The greatest longevity among a large number of lots of ticks which became adult during 1909 was between 320 and 353 days. This record was made on a single male which molted between August 30 and September 1, 1909, and died between July 18 and August 18, 1910. The other lots which became adults during 1909 lived between 117 and 321 days. Among over a hundred lots, the molting of which was observed by us during 1910, the longevity ranged between 66 and 367 days. The majority of these lots contained some individuals which lived over 250 days and a considerable number showed a longevity of over a year.

Still more remarkable is the longevity exhibited by lots of adults collected in Montana during the spring of 1910 by Mr. W. V. King, before they had attached to hosts. Among the several lots observed the longevity varied from 55 to 413 days. Four of these lots which were obtained from shrubbery between March 18 and May 31, 1910, lived more than 320 days. The greatest longevity observed occurred in a lot of one male and two females collected at Victor, Mont., April 2, 1910. One female lived until May 20, 1911, or a period of 413 days. It should be borne in mind that these collected individuals undoubtedly came to maturity in the fall of 1909 and passed the winter in hibernation. Therefore we should add about six months to the longevity observed, making a total longevity of about 600 days. It is thus apparent that ticks which become adult in the latter part of the summer may survive until the second spring following. Adults collected from animals during the spring and summer of 1910 were found to live between 40 and 262 days. The females in these lots varied from unengorged to about one-eighth engorged. The length of the life of the sexes appears to be about the same.

All longevity records are based on ticks kept in tubes on moist sand in the laboratory.

There is a marked tendency for adults which are awaiting a host to climb to a considerable height on shrubs or trees so that they are in a position to be brushed off by large animals when passing. When disturbed they either grasp any passing object with the forelegs, or curl the legs up, drop, and catch hold of any object which they happen to strike in falling. When one moves an object near specimens which are awaiting a host, the ticks begin to extend and wave the forelegs, the other legs also being frequently extended. Engorged females also use the legs for feelers in their search for suitable places for concealment In one case an engorged female was observed to extend and wave all of the legs but one, which was used to cling to the inclined surface upon which it was crawling.

Newly molted adults show no desire to attach to hosts. In fact, the habit of attaching to hosts in the spring months only is so firmly fixed in adult ticks of this species that it is very difficult to induce them to attach to hosts at other seasons of the year. We have observed both sexes to remain motionless in tubes in the laboratory for weeks and even months at a time During this resting period the ticks usually keep the legs closely curled up to the body and it is often difficult to induce activity.

About twenty trials were made between September 1 and December 15 to secure the attachment of adults which had matured the preceding spring. Bovines, guinea pigs, and rabbits were used as hosts. In only two instances were any specimens induced to attach and in neither of these cases did engorgement or mating take place. In one of these instances 3 females and 2 males attached when applied to a guinea pig on October 4, 1910. All of the specimens changed their points of attachment a number of times, but no perceptible engorgement took place. One of the females remained on the host until December 22, or 79 days, and the male did not disappear from the host until a few days later. During the early spring months no great difficulty was encountered in getting adults to attach to guinea pigs, rabbits, goats, or bovines.

When placed on a host the adults usually crawl about carefully for some time before attaching. On small mammals they attach to any part of the body, but on large mammals, in nature, we have found them to attach mainly between the legs, along the escutcheon, belly, and dewlap, and sometimes on the shoulders. On horses they frequently attach under the jaws and sometimes in the mane. In one instance a number of males and females were placed on the legs and dewlap of a yearling bull at 4 p. m.; by 5 p. m. a considerable number of them had reached the animal's back and were crawling about there. The next morning all of the specimens that could be found (3 males and 7 females) were attached on a small area on the top of the shoulders.

Mating occurs on the host. We have not observed a male to attach beneath a female before it had fed for at least 4 days. Usually a feeding period of from 6 to 8 days appears to be necessary before the males start in search of mates. The males have been observed to insert their mouthparts in the genital opening of the females immediately after passing beneath them. In one instance, at least, the palpi of the male were not inserted with the hypostome. The act of copulation appears to occupy only a short time, probably less than an hour, then the males attach close to their mates, the ventral surfaces together, and the legs of the males clasping the legs or body of the females. It seems quite certain that copulation takes place more than once while the males remain beneath the females. In a

number of instances males have been observed to remain with females until the latter had become engorged and dropped, when they sought other mates. As many as three females have been seen to be fertilized by a single male. In many cases the females are nearly engorged before being visited by a male. Some of our observations indicate that the males usually start in search of mates in the early morning or late in the evening. Males have been observed to remain on a host for two months, at the end of which time they were removed. During this period two successive lots of females were applied and engorged, the males fertilizing both of them.

The period of engorgement at Dallas, Tex., varied from 8 to 17 days. After fertilization takes place engorgement appears in most cases to proceed more rapidly.

TABLE LXXXI.—*Engorgement of adults of Dermacentor venustus.*

Date females applied.	Host.	Number.	Females dropped engorged—days following application.								Total number dropped.
			8	9	10	11	12	13	14	17	
May 15, 1908	Bovine	2	1							1	2
June 15, 1909	.....do	2							1		1
Mar. 19, 1910	Guinea pig	2		1							1
Mar. 29, 1910	.....do	1		1							1
Apr. 1, 1910	Bovine	4				2	2				4
Apr. 13, 1910	.....do	1		1							1
Apr. 15, 1910	Guinea pig	1				1					1
May 4, 1910	Bovine	3	1		1			1			3
July 23, 1910	Rabbit	5							1		1
Mar. 29, 1911	Bovine	14		5	1				1		7

LIFE CYCLE.

The larvæ have a longevity of about 2 months. They engorge in from 2 to 8 days after attaching to a host and may molt as soon as 6 days after dropping, a total effective temperature of 272° F. being required for this molt. Nymphs may live for more than 300 days. They engorge in from 4 to 9 days after attaching to a host and they may molt as soon as the eleventh day after dropping, a total effective temperature of 485° F. being necessary to produce this transformation. Adults have been observed to live for 413 days and since this record was made on ticks which were collected in the spring, they must have had a total longevity of about 600 days. Females may engorge as soon as 8 days after finding a host, commence depositing eggs as soon as the fifth day following dropping, and deposit as many as 7,396 eggs. Embryonic development may be completed in 16 days, an effective temperature of 614° F. being required.

It appears that the life cycle of this tick usually requires 2 years. The winter is spent in the unengorged nymphal and the unengorged adult stages. The adults begin to emerge from hibernation soon after the snow disappears. The great majority of them attach to

the large mammals between March 10 and June 10, then engorge and deposit eggs from which larvæ hatch. These larvæ engorge upon small mammals and drop and molt to nymphs which, in some cases, may remain quiet until cool weather begins and then go into hibernation to appear as unengorged nymphs the following spring. Others probably become engorged and in the fall produce adults which pass the winter in that stage. The over-wintered nymphs appear somewhat later than the adults; they attach to small mammals, become engorged, and produce adults. The majority of these adults probably remain quiet during the summer and go into hibernation the following winter.

ECONOMIC IMPORTANCE.

While this species appears to be quite abundant in certain portions of the northwestern United States and more or less annoying to domesticated and wild animals, it is of particular importance because of the rôle it plays in the transmission of the causative organism of Rocky Mountain spotted fever. This is a disease of man which occurs in several of the Rocky Mountain States. It is of extreme importance in the Bitter Root Valley of Montana, where a number of cases occur each year, among which the mortality is usually about 70 per cent. In Idaho, however, the disease is much less virulent, the mortality not running above 5 to 8 per cent, although the number of cases in the southern part of this State frequently exceeds 300 per year. The occurrence of the disease is largely confined to the spring months March to June inclusive, or the period during which the adult ticks are most active.

NATURAL CONTROL.

Few observations relating to the natural enemies of this species appear to have been made. Chickens have been found to devour the engorged females with avidity when the ticks were fed to them. No doubt fowls eat a large number of ticks which drop from animals in the barnyard. In Colorado a species of blackbird was seen to devour the engorged ticks as they fell from cattle. Engorged females have been observed to be eaten by tame rabbits upon which specimens were being engorged. The little black ant, *Monomorium minimum*, was found on a number of occasions to have entered pill boxes which contained engorged larvæ and destroyed dozens of specimens.

ARTIFICIAL CONTROL.

As has been pointed out, the adults of the Rocky Mountain spotted-fever tick feed almost exclusively on the large domestic animals, while the small rodents are the principal hosts of the immature stages. This immediately suggests the idea of destroying the adult ticks on domestic animals. On account of the fact that many of the adults

which appear in the late summer or fall from overwintered nymphs will hibernate before engorging, it will be necessary to continue the treatment of the hosts for at least two seasons. Dipping, swabbing, or hand picking would probably not be necessary except between the first appearance of the ticks in spring and June 15. As has been pointed out by Dr. Ricketts, the destruction of the small mammals which act as hosts for the immature stages would also aid in lessening the numbers of the tick.

THE PACIFIC COAST TICK.

Dermacentor occidentalis Neumann.

The common name of this tick is derived from the fact that it is known to occur only in the Pacific coast region of the United States.

DESCRIPTIVE.

Adult (Plate XII, figs. 8–12).—Males 2.8 by 1.6 mm. to 4.2 by 2.3 mm. Females, unengorged, 2.9 by 1.8 mm. to 3.6 by 2 mm.; engorged, 9 by 6.1 by 3.3 mm. to 11.8 by 7.6 by 5.6 mm. Unengorged males and females reddish brown, scutum in both sexes well covered with a whitish color resembling bloom, somewhat iridescent, interrupted by many red punctures; the same color on dorsal side of legs as on scutum. Engorged female steel-gray, dorsum with an olive-green surface color, which covers the gray except in small spots, thus giving a mottled appearance.

Nymph.—Unengorged, 1.13 by 0.63 to 1.26 by 0.65 mm.; engorged, 3.10 by 2.16 by 1.11 mm. Color light brown, lateral portions of scutum darker, the intestines, which show through, dark brown. Capitulum 0.32 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.488 mm. long by 0.557 mm. wide.

Larva.—Unengorged, 0.643 by 0.426 mm.; engorged, 1.316 by 0.916 by 0.603 mm. Capitulum 0.139 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.23 mm. long by 0.339 mm. wide. Color, unengorged, reddish brown; engorged, bluish gray.

Egg.—Ellipsoidal, amber to brown in color, shining, smooth. The maximum size of 10 eggs was 0.517 mm. by 0.402 mm., the minimum size 0.502 mm. by 0.387 mm., and the average size 0.51 mm. by 0.395 mm.

HOST RELATIONSHIP.

The host of the type specimen is the deer. As yet little is known regarding the hosts of the immature stages. They attach and engorge readily upon guinea pigs, rabbits, and bovines. Over 80 lots of adult ticks, in which the host animal was given, have been received from correspondents. The frequency of occurrence on

different hosts was as follows: Cattle, 30; horse, 22; man, 16; deer, 4; mule, 4; dog, 3; ass, 1; rabbit, 1; sheep, 1. While cattle, horses, and man are the hosts upon which most of our collections have been made, deer act as hosts for large numbers of adults. In some cases they are said to be infested with thousands of specimens.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 15.)

The type locality for this species is Occidental, Cal. Although this species has been reported from Texas, New Mexico, and Arizona, as well as California, it is very doubtful if the records from Texas, New Mexico, and Arizona are correct. Our records indicate that the species is confined to the Coast Range and Sierra Nevada Mountains in California and Oregon and the small mountain ranges in southwestern California. The species occurs in great abundance in the extreme southern part of California, and it is therefore almost certain to occur southward in Lower California and western Sonora.

LIFE HISTORY.

No previous work seems to have been done on the life history of this species. Investigators of Rocky Mountain spotted fever have published a number of notes regarding the life history of *Dermacentor venustus* under the name *Dermacentor occidentalis.*

The egg (Table LXXXII).—In the laboratory in June, at a mean temperature of 87.19° F., deposition began in one case in 4 days. In April, with a mean temperature of 66.18° F., one tick had a preoviposition period of 14 days. The longest preoviposition period actually noted was 17 days. This record was on a female which was collected and mailed to the laboratory, hence the temperature and moisture conditions were not normal. The average preoviposition period of 4 females dropped in April and May was 7¾ days. The average preoviposition of 17 lots of females collected during the period from March to June, inclusive, was 10.4 days. During April and May, 4 ticks showed a deposition period of from 27 to 39 days, with an average of 31¼ days. The mean temperature during the shortest period was 74.17° F. and during the longest period it was 70.99° F. These females died in from 1 to 7 days after deposition was completed. The average number of eggs deposited by the 4 females was 3,210 and the maximum number deposited by an individual was 4,555.

The minimum incubation period under laboratory conditions was 21 days. This record was made during June, 1910. The total effective temperature required for embryonic development appears to be at least 842° F. The last two lots of eggs, the hatching of which is

recorded in the following table, were kept in an incubator during incubation and removed therefrom when hatching was complete.

FIG. 15.—The Pacific Coast tick, *Dermacentor occidentalis:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots show the probable range of the tick. (Original.)

The incubation period was reduced to 16 days in these two instances, during which time the mean temperature was about 90° F.

TABLE LXXXII.—*Preoviposition, incubation, and longevity of larvæ of Dermacentor occidentalis.*

Date engorged female dropped or collected.	Deposition began.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
						Maximum.	Minimum.	Average daily mean.	Total effective.
1910.	1910.	1910.	*Days.*	1910.	*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
Apr. 2 (collected)	Apr. 15	May 19	35	Before July 16.	58—	91	43	70.16	950.6
Do	Apr. 14	May 17	34	July 16–Aug. 4.	105–124	91	43	70.72	942.48
Apr. 11 (collected)	Apr. 21	May 25	35	July 18–Aug. 4.	54–71	91	43	71.43	1,012.0
Apr. 12 (collected)	Apr. 26	May 26	31	do	53–70	91	52.5	73.19	935.75
Apr. 13 (dropped)	Apr. 27	May 28	32	Before July 18.	51—	91	58.5	74.23	999.50
May 3 (collected)	May 10	June 16	38	July 18–Aug. 4.	32–49	100	59	77.92	1,326.9
Do	May 13	June 7	26	do	41–58	100	59	77.07	885.75
May 9 (dropped)	May 16	June 10	26	Aug. 4–12	55–63	100	60	79.28	943.25
May 11 (collected)	May 20	June 12	24	do	53–61	100	60	80.09	890.25
May 13 (collected)	May 23	June 14	23	July 18–Aug. 4.	44–61	100	60	80.25	856.75
May 15 (collected)	May 24	June 16	24	do	32–49	100	60	80.71	905.25
May 29 (dropped)	June 4	June 24	21	do	24–41	97	66	83.1	842
June 20 (dropped)	June 24	July 14	21	Aug. 12–20	29–37	98	73.5	85.7	896.75
Nov. 15 (collected)	Dec. 12	Dec. 27	[1] 16	Mar. 18, 1911	81			90 (about)	
Do	Dec. 16	Dec. 31	[1] 16	Mar. 14. 1911	73			90 (about)	

[1] Kept in incubator during incubation.

The larva (Tables LXXXII–LXXXV).—The longevity of the larvæ of this species is somewhat shorter than that of most of the other species of the genus Dermacentor. The greatest longevity accurately recorded occurred in the case of a lot of larvæ which hatched May 17 and on subsequent days. The longest-lived larvæ of this lot died between 105 and 124 days after hatching began. A large number of records of larval longevity were made on the progeny of individual ticks. In the majority of the lots all larvæ were dead within two months after the hatching of the eggs began. All of the records on longevity were made upon larvæ kept in tubes with cotton stoppers, on moist sand in the laboratory.

Engorgement may be completed as soon as 3 days after attachment to a host. The greatest number of engorged larvæ dropped from the host on the third, fourth, and fifth days after attachment. A single larva was found to have dropped the second day, but since this specimen was not fully engorged it is quite probable that it was rubbed off by the host. This statement probably applies to all larvæ which were found to have dropped before becoming fully engorged. The longest period required for engorgement was 7 days. In most instances larvæ were found to attach within a few hours after being applied to a host. In our experiments only a small percentage of the number of larvæ put on a host ever reached engorgement.

TABLE LXXXIII.—*Engorgement of larvæ of Dermacentor occidentalis.*

Date larvæ applied.	Host.	Number.	Larvæ dropped engorged—days following application. 1	2	3	4	5	6	7	Total number dropped.	State of engorgement.
1910.											
May 24	Bovine	1,000	0	1	38	10	3			52	Two-thirds to fully.
June 10	do	700	0	0	27	6				33	Fully.
June 21	do	400	0	0	0	0	2			2	(?)
June 27	do	150	0	0	11	11				22	Fully.
July 6	Guinea pig	500	0	0	130	60	206	4		400	Two-thirds to fully.
July 9	Bovine	300	0	0	0	4	2			6	Fully.
July 19	do	200	0	0	0	8	6	1		15	Two-thirds to fully.
Aug. 9	do	200	0	0	4					4	Fully.
Aug. 25	Guinea pig	50	0	0	0	0	10	4	1	15	Do.

TABLE LXXXIV.—*Rapidity of engorgement of larvæ of Dermacentor occidentalis applied to guinea pig at 11 a. m., July 6, 1910.*

Engorged larvæ dropped (tray examined).	Number.	Period from application.	Percentage of total dropped.	Engorged larvæ dropped (tray examined).	Number.	Period from application.	Percentage of total dropped.
		Hours.				*Hours.*	
July 9, 9 a. m.	6	70	1.5	July 10, — p. m.	35	(?)	8.75
July 9, 2 p. m.	10	75	2.5	July 11, 9 a. m.	117	94	29.25
July 9, 4.35 p. m.	90	77½	22.5	July 11, 11.30 a. m.	78	96½	19.50
July 9, 5.05 p. m.	19	78	4.75	July 11, 5 p. m.	11	102	2.75
July 9, 5.30 p. m.	5	78½	1.25	July 12, 9 a. m.	4	118	1.00
July 10, — p. m.	25	(?)	6.25				

In July, at a mean temperature of 86.82° F., molting began in 6 days. This transformation appears to require a total effective temperature of 263° F.

TABLE LXXXV.—*Molting of engorged larvæ of Dermacentor occidentalis.*

Date engorged larvæ dropped.	Host.	Number.	Engorged larvæ molted—days following dropping. 6	7	8	9	10	11	12	Total number molted.	Temperature from dropping to date first tick molted. Maximum.	Minimum.	Average daily mean.
1910.											°*F.*	°*F.*	°*F.*
May 27, a. m	Bovine	38			5	[1]	25	0	2	32	100	71.50	83.47
May 28, a. m	do	10					4			4	100	73	83.57
May 29, a. m	do	3					1			1	100	73	84.04
June 13, a. m	do	15			3	4	3			10	97	69	83.05
June 13, p. m	do	8					3	1		4	97	69	83.05
June 14, a. m	do	6			2	2				4	97	69	84.52
June 30, p. m	do	11			5			2		7	98	73.5	86.64
July 9	Guinea pig	16			[1]	16				16	103.5	76	86.4
July 9, p. m	do	90			[1]	15				15	103.5	76	86.4
July 9, p. m	do	24			[1]	24				24	103.5	76	86.4
July 10, a. m	do	25		[1]	19					19	103.5	76	86.78
July 11, a. m	do	117	[1]	100						100	103.5	76	86.82
July 11, p. m	do	89	[1]	78	0	2				80	103.5	76	86.82
July 12, a. m	do	4	2							2	103.5	76	86.83
July 13, a. m	Bovine	4		4						4	103.5	74	87.75
July 23, a. m	do	6			4					4	102	80	89.29
Aug. 12, a. m	do	1		1						1	103.5	82	92.37
Aug. 30, a. m	do	4		1		1	1			3	98	75	87.31
Aug. 30, p. m	do	6		5						5	98	75	87.31
Aug. 31, a. m	do	4					2			2	98	72.50	86.16
	Total	481								337			

[1] The larvæ which molted on this day are included with those on the following day.

The nymph (Tables LXXXV–LXXXVII).—The longevity of the nymphs of this tick is shorter than that of any other species of Dermacentor studied by us with the possible exception of those species which molt on the host. The records made indicate that during the hot summer months the longevity ranges between 40 and 60 days. The greatest longevity observed was between 76 and 108 days. This record was made in the fall months. These nymphs were kept in glass tubes with cotton stoppers on moist sand in the laboratory. It is probable that during cool weather a somewhat greater period of longevity would occur.

TABLE LXXXV.—*Longevity of nymphs of Dermacentor occidentalis.*

Date larvæ molted to nymphs.	Number.	Number put on host.	All larvæ dead.	Larval longevity.
1910.			1910.	*Days.*
June 4–8	37	0	July 18 to Aug. 4	40–61.
June 21–24	18	0	Aug. 4 to Aug. 12	41–52.
July 17–20	300	230	Aug. 12 to Sept. 24	23–69.
July 31 to Aug. 12	4	0	Before Oct. 26	Less than 75.
Aug. 17	1	0	do	Less than 70.
Sept. 6–10	10	0	Nov. 25 to Dec. 23	76–108.

TABLE LXXXVI.—*Engorgement of nymphs of Dermacentor occidentalis.*

Date nymphs applied.	Host.	Number.	Nymphs dropped—days following application. 3	4	5	6	7	8	9	Total number dropped.	State of engorgement.
1910.											
July 19 [1]	Guinea pig	(?)	8	3	5	4	....	....	....	20	Fully.
July 26	do	30	....	....	....	7	1	1	1	10	One-fourth to fully.
July 30	Bovine	4	....	....	....	1	....	....	....	1	One-third.
Aug. 6	Rabbit	200	....	12	32	18	8	....	2	72	One-half to fully.
Aug. 5 [1]	Guinea pig	(?)	....	....	2	....	....	....	....	2	Fully.

[1] These lots were accidental infestations, hence the exact date of attachment is not known.

The shortest period of engorgement accurately observed was 4 days; the longest, 9 days. In the last instance the nymphs were still only about one-half engorged and were probably scratched off by the host. The weighted average engorgement period of all nymphs upon which accurate records were made is 5.56 days. Attachment was observed to take place, in most cases, almost immediately after the ticks had been placed on the host.

TABLE LXXXVII.—*Molting of engorged nymphs of Dermacentor occidentalis.*

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping. 13	14	15	16	17	18	19	21	22	Number molted. Male.	Female.	Total.	Temperature from dropping to date first tick molted. Maximum.	Minimum.	Average daily mean.
1910.															°F.	°F.	°F.
June 12, p. m.	Guinea pig	1									1♀		1	1	103	77.50	90.10
July 22, a. m	do	4			1♀		1♂, 1♀					1	2	3	103	77.50	90.19
July 22, p. m	do	4				([1])	1♂, 3♀					1	3	4	98	66	69.36
July 23, a. m	do	3			2♂	1♀						2	1	3	103	79	90.27
July 24, a. m	do	5				1♂, 2♀	1♀	1♀				1	4	5	103	79	90.23
July 25	do	4					1♂		1♂	1♂		3	0	3	103	79	90.21
July 30	do	1				1♂						1	0	1	103.5	79	91.04
Aug. 1, a. m	do	7		3								?	?	3	103.5	79	91.18
Aug. 2, a. m	Rabbit	1			1♀							0	1	1	103.5	79	91.00
Aug. 3, a. m	Guinea pig	1					1					?	?	1	103.5	79	90.96
Aug. 10	do	2		1♂		1♂						2	0	2	104.5	79	92.32
Aug. 10, a. m	Rabbit	2		2♂								2	0	2	104.5	79	92.32
Aug. 10, p. m	do	10	2♀	1♂	2♂, 2♀	1♂, 1♀	1♀					4	6	10	104.5	78	92.38
Aug. 11, a. m	do	10			1♂	1♂	1♂, 2♀	1♀				3	3	6	104.5	73	91.32
Aug. 11, m. noon	do	7	1♂		1♂, 1♀		([1])	1♂, 1♀				3	2	5	104.5	79	92.44
Aug. 11, p. m	do	13		1♀	3♂, 2♀	1♂, 2♀	1♂, 1♀	1♂				6	6	12	104.5	79	92.13
Aug. 12, a. m	do	12	1♀		2♂	([1])	1♂, 3♀	1♂	1♀			4	5	9	104.5	80	91.96
Aug. 12, p. m	do	6			1♂, 1♀	2♀	1♂	1♀				2	4	6	104.5	73	90.53
Aug. 13, a. m	do	3			([1])	1♂, 1♀						1	1	2	104.5	73	90.15
Aug. 13, p. m	do	5			1♀	3♂	1♂					4	1	5	104.5	73	90.15
Aug. 15, a. m	do	2			2♂							2	0	2	104.5	73	89.67
	Total	103										42	40	86			

[1] The ticks which molted on this date are included with those recorded on the following day.

In August, 1910, at a daily mean temperature of from 91.96° to 92.44° F. molting commenced on the thirteenth day. The longest period from dropping to molting was 22 days. This occurred at a daily mean temperature of 69.36° F. The males and females began to appear about the same number of days after dropping. The weighted average molting period of 42 nymphs which transformed to males was 15.89 days. In the case of 40 females this average was 16.22 days. The weighted average period from dropping to molting for all nymphs observed was 15.62 days. A total effective temperature of 636.5° F. seems to be required for this transformation.

The adult (Tables LXXXVIII–LXXXIX).—The number of males and females which molted from nymphs was practically equal. The greatest longevity which has been observed was 359 days. This record was made on a lot of 29 males and 29 females which molted from nymphs August 10, 1910. The last male in this lot died May 31, 1911. It had lived 294 days. The females appear to have a slightly greater longevity than do the males; this is particularly noticeable

among those ticks which have once been attached to a host in the adult stage. Hot weather also appears materially to shorten the longevity of both sexes.

TABLE LXXXVIII.—*Longevity of adults of Dermacentor occidentalis.*

Date molted or collected.	Number.		All dead.	Longevity.
	Male.	Female.		
1910.				*Days.*
Molted, July 4	0	1	Oct. 18–Nov. 28, 1910	106–147
Molted, Aug. 10	29	29	Aug. 4, 1911	359
Molted, Aug. 15	1	....	May 27, 1911	285
Molted, Aug. 15–20	2	2	May 8, 1911	266
Molted, Aug. 17	0	1	Nov. 28–Dec. 20, 1910	103–125
Molted, Aug. 24	2	0	May 20, 1911	269
Collected, Apr. 2	0	1	July 19–Aug. 18, 1910	118–147
Do	1	7	June 7, 1910	66
Collected, Apr. 5	2	8	Aug. 18–31, 1910	135–148
Collected, Apr. 8	8	4	June 18–July 18, 1910	71–101
Collected, Apr. 27	0	5	July 18–Aug. 18, 1910	82–113
Collected, May 28	0	2	....do	51–82
Collected, Oct. 1	6	5	Apr. 5, 1911	166
Collected, Oct. 26	0	1	Mar. 20, 1911	145

Copulation of this species has not been observed before attaching to a host. Mating has been seen to take place upon bovine hosts any time between one and several days after attachment. In one case a female became fully one-half engorged before she was visited by a male. One female which was not observed to be fertilized became nearly engorged and dropped in about the normal engorgement period. However, no eggs were deposited by this individual.

TABLE LXXXIX.—*Engorgement of adults of Dermacentor occidentalis on bovines.*

Date females applied.	Number.	State of engorgement.	Date attached.	Females dropped engorged—days following attachment.								State of engorgement.
				2	4	6	7	9	10	17	Total number dropped.	
1910.			1910.									
Apr. 9	5	Slightly to one-fifth.	Apr. 9	...	...	1	...	...	...	...	1	Fully.
Apr. 22	2	Unengorged.	Apr. 22	...	...	...	...	...	...	1	1	Two-thirds.
May 9	10	Unengorged to one-eighth.	May 9	4	1	...	...	...	...	...	5	One-fourth to two-thirds.
May 20	1	Unengorged.	May 20	...	...	...	...	1	...	...	1	One-half.
June 4	3	Slightly	June 4	...	...	1	...	...	...	...	1	Two-thirds.
June 14	2	....do	June 15	...	...	...	1	...	...	...	1	Do.
Aug. 26–31	8	Unengorged.	Aug. 31–Sept. 4	...	...	...	1	...	1	...	2	Fully.
Sept. 22	4	....do	Sept. 24	...	...	...	1	...	...	...	1	One-eighth.

Males have been observed to remain upon a host for 31 days. Females which had become one-fifth engorged upon one host were found to attach to another host when given an opportunity. In most cases ticks applied to a bovine attached within less than one day thereafter, but in a few instances both males and females were

found to remain unattached for 4 or 5 days, some of these dying in the meantime. The females which became detached before becoming fully engorged, as indicated in Table LXXXIX, were undoubtedly dislodged by the rubbing of the host. The shortest period in which females were known to become fully engorged was 6 days; the longest period was 17 days. In the last instance the female was only two-thirds engorged when she was detached.

LIFE CYCLE.

A period of at least 105 days elapsed between the beginning of hatching of the eggs deposited by a female and the death of the last larva. The larvæ may engorge in 3 days after attachment and in summer molt as soon as 6 days after dropping. The transformation from larvæ to nymphs requires a total effective temperature of 263° F. Nymphs may live at least as long as 76 days during cool weather; they engorge as soon as 4 days after attachment and may molt as soon as 13 days after dropping. The molting period for nymphs which become males and those which become females is practically the same. A total effective temperature of 636° F. is required to produce this molt. Adults may live as long as 359 days. Females may engorge in 6 days, commence depositing in 4 days after dropping, and deposit as many as 4,555 eggs. The eggs hatch as soon as 21 days after deposition and appear to require a total effective temperature of about 842° F. for incubation.

This tick has been found to occur in nature at all seasons of the year. The adults appear to become most numerous during the rainy season. Many engorged females are to be found on hosts during December.

ECONOMIC IMPORTANCE.

Owing to the fact that this tick frequently attacks man and often occurs in great abundance on domestic live stock, it is of considerable economic importance in California and Oregon. Its presence throughout the entire season in greater or less numbers also increases its importance. Where it occurs it is usually spoken of as the "wood tick." In central and western California and western Oregon it is the most common tick which attacks man. A number of cases have been brought to our attention where the bite of this tick has caused considerable local inflammation which, in some cases, has required a physician's attention. It is quite common for the rostrum to be broken off when the ticks are removed and in such cases the irritation and itching usually persists for several weeks.

Although numerous authors have used the name *Dermacentor occidentalis* in connection with Rocky Mountain spotted fever, it is doubtful if this species is concerned in the transmission

of that disease. The use of the name was due to confusion regarding the identity of the tick *Dermacentor venustus*, which is the known transmitter of this disease in nature.

NATURAL CONTROL.

No natural enemies of this species have been observed by the writers. However, it is probably subject to the attack of the various predaceous enemies of other tick species. McAtee (1911a) states that ticks of this species have been found to be eaten by the dwarf hermit thrush (*Hylocichla guttata nana*).

ARTIFICIAL CONTROL.

The comparatively short longevity of the larvæ and nymphs of this species indicates that it may be possible to practice the rotation method of eradication. This method appears to be more promising than the use of dips on account of the fact that the engorgement period of the immature stages is quite short and usually takes place on small wild mammals. The occurrence of the species throughout the year is also an obstacle to the practice of dipping or mopping animals with tickicides.

THE AMERICAN DOG TICK.

Dermacentor variabilis (Say).

The common name of this tick is given it because in this country it is the most widely distributed species which commonly attacks the dog.

DESCRIPTIVE.

Adult (Pl. XV, figs. 5–11).—Males from 3.5 by 2.5 to 4.5 by 2.5 mm. Females, unengorged, about 3.75 by 2.25 mm.; engorged, 10 by 7 by 5 to 15.5 by 11.2 by 7.4 mm. Male reddish brown, dorsum with irregular white marks; female reddish brown, scutum with a white band on the lateral margin, broadening posteriorly; a brown marginal stripe near each eye and sometimes two white median stripes.

Nymph (Pl. XV, figs. 2–4).—Unengorged, about 1.5 by 1 mm.; engorged, 3.5 by 2 by 1 mm. to 4 by 3 by 2 mm.; average 3.5 by 2.5 by 1.5 mm. Color, unengorged, pale yellowish brown; posterior margin of scutum dark brown, lateral margins of scutum with brick-red markings; in living specimens the intestines are visible as brown bands through the body walls; engorged, slate-gray. Capitulum 0.287 mm. long (from tip of palpi to base of emargination of scutum); scutum 0.488 mm. long by 0.526 mm. wide.

Larva (Pl. XV, fig. 1).—Unengorged, about 0.60 by 0.35 mm.; engorged, 1.5 by 1 mm. Color, unengorged, pale yellow; lateral margins of scutum brick-red; engorged, dull gray. Capitulum 0.17

mm. long (from tip of palpi to base of emargination of scutum); scutum 0.255 mm. long by 0.32 mm. wide.

Egg.—Ellipsoidal, pale yellowish brown, shining, smooth. The average size of those measured was 0.527 by 0.379 mm.

HOST RELATIONSHIP.

The host of the type is not recorded. The dog is the most common host of the adult stage of this species. Out of 112 lots collected by agents of the bureau the following numbers of lots were taken on the different hosts listed: Dog 62, fox squirrel 9, raccoon 6, opossum 6, ox 5, badger 3, coyote 3, skunk 3, deer 2, man 2, wolf 2, ass 1, Mexican lion (*Felis hippolestes aztecus*) 1, fox 1, hog 1, horse 1, rabbit 1, weasel 1, wild cat 1. The lot from the Mexican lion, consisting of 9 males and 3 females, was collected by Mr. D. K. McMillan at Raymondville, Tex., November 20, 1910.

No larvæ known to be of this species have been collected, but a considerable number of nymphs have been taken on fox squirrels and one lot was collected on a swamp rabbit (*Lepus aquaticus*). Adults of both sexes were taken on the fox squirrels along with the nymphs. Most of the lots collected on this host were taken by Mr. J. D. Mitchell in March and April, 1909. In rearing experiments larvæ attached to a bovine, but failed to attach to dogs, even after several attempts were made.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 16.)

The locality from which the type was described is not recorded.

The determination of the distribution of this species is complicated through questionable identification due to the fact that, superficially, it closely resembles several other species.

The species is common throughout the eastern half of the United States. It is recorded from Alaska, Labrador, Ontario, and Nova Scotia on the north and its range extends southward through the United States to the Gulf coast. There is also one record from Mexico. Although the species has been listed from Colorado, New Mexico, and Arizona, our investigations indicate that it does not normally occur in those States. There is, however, a considerable area in western California and southwestern Oregon where the species is very common. In this region and in the Central and Southern States the species appears to occur most abundantly.

LIFE HISTORY.

Observations on the biology of this tick have been published by Morgan (1899, pp. 133, 135), Hunter and Hooker (1907, pp. 50–51), and by Hooker (1908, p. 47).

The egg (Table XC).—The minimum preoviposition period for a large number of ticks observed at different times of the year was 5 days and the maximum 14 days. This minimum preoviposition period was observed in a number of instances during the summer

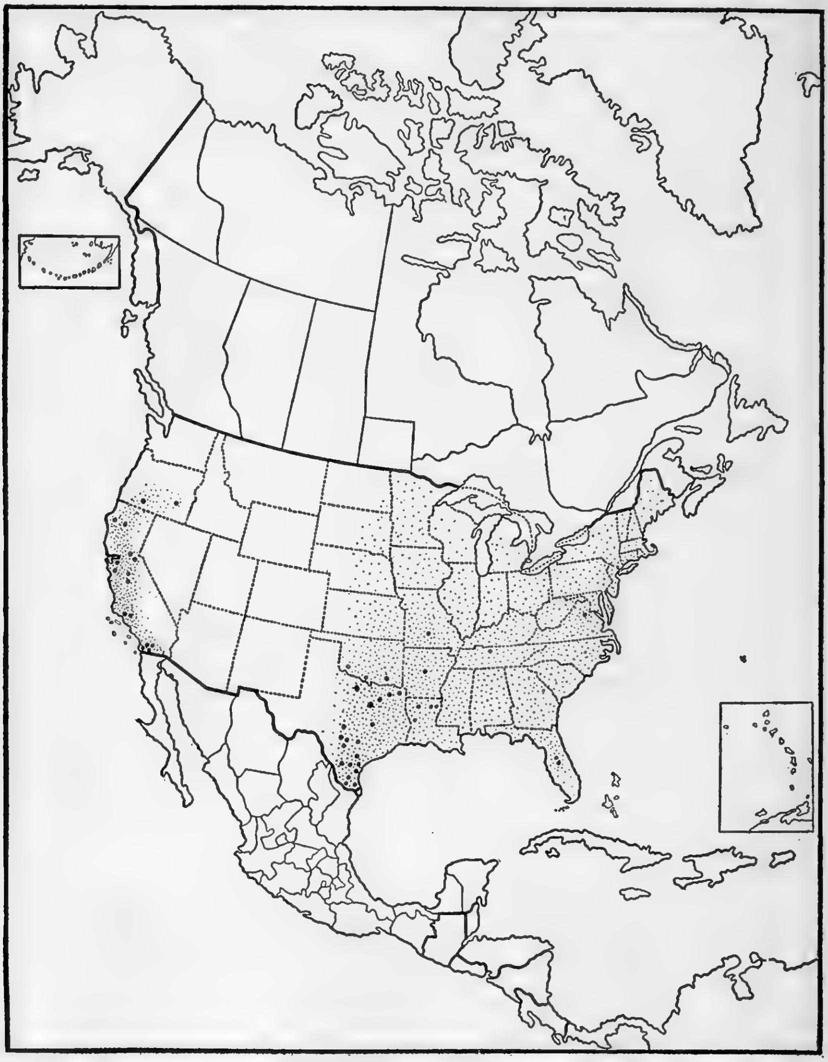
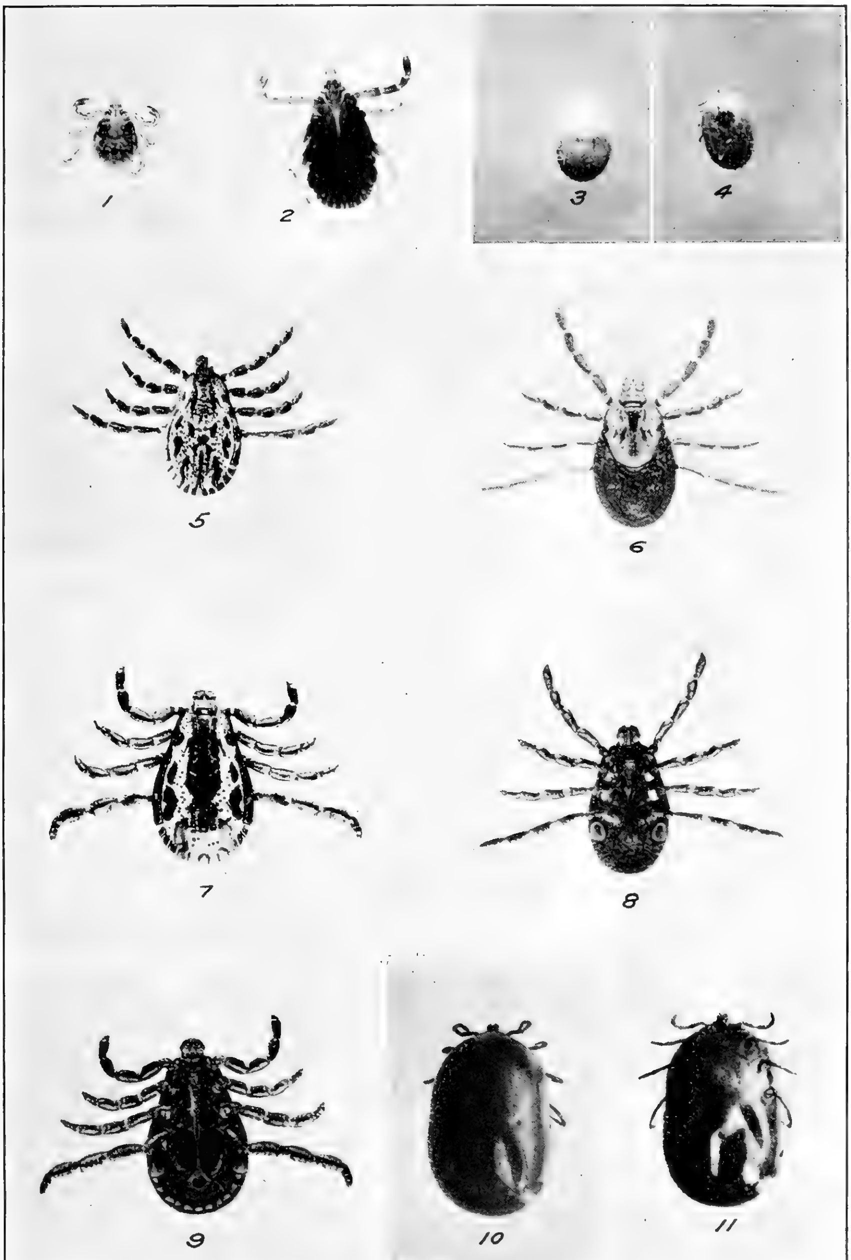


FIG. 16.—The American dog tick, *Dermacentor variabilis:* Distribution in the United States. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the tick. (Original.)

months, while the maximum period was recorded once in March and once in April, 1909. The mean temperature during the shortest period was 80° F. The period of oviposition varied from 14 to 29 days with an average of 22.3 days. A tick which was collected on a



THE AMERICAN DOG TICK, DERMACENTOR VARIABILIS.

Fig. 1.—Unengorged larva. Fig. 2.—Unengorged nymph (balsam mount). Fig. 3.—Engorged nymph about to molt to female. Fig. 4.—Engorged nymph about to molt to male. Fig. 5.—Male, dorsal view (Texas form). Fig. 6.—Unengorged female, dorsal view. Fig. 7.—Male, dorsal view (Oregon form). Fig. 8.—Unengorged female, ventral view. Fig. 9.—Male, ventral view. Fig. 10.—Engorged female, dorsal view. Fig. 11.—Engorged female, ventral view. (Original.)

dog August 10, 1909, measured 15.5 by 11.2 by 7.4 mm. It began depositing on the sixth day and continued depositing for 23 days, during which time 6,855 eggs were deposited. This is the maximum number of eggs recorded by us for the species, but Prof. H. A. Morgan (1899) has recorded 7,378 as being deposited by one tick between May 8 and June 26. The minimum number of eggs deposited by 11 ticks was 2,808, the average 4,568.

The minimum incubation period for eggs kept in tubes out of doors was 24 days. This record was made on eggs deposited August 17, 1907. Eggs kept in the laboratory at a mean temperature of 84° F. hatched in 20 days. An effective temperature of at least 825° F. appears to be required for their incubation.

TABLE XC.—*Incubation and longevity of larvæ of Dermacentor variabilis.*

IN LABORATORY.

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
					Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	*Days.*		*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
Apr. 11	May 18	38			86	47	70.41	1,041.50
June 4	June 28	25	Oct. 4, 1908	98	91.5	69	80.98	949.50
June 10	July 3	24	Oct. 6, 1908	95	91	69	80.33	895.75
June 12	July 14	33	Oct. 4, 1908	82	93	70.5	81.31	1,264.25
July 4	July 25	22	May 17, 1909	296	95	70.5	83.26	888
July 6	July 27	22	June 10, 1909	318	95	74	83.86	899
July 7	do	21	June 27, 1909	335	95	74	83.98	860.50
July 11	July 30	20	Apr. 16–May 7, 1909	260–281	95	74	84.26	825.25
July 12	Aug. 1	21	Nov. 9–16, 1908	100–107	95	74	84.29	867
July 15	Aug. 4	21	May 8–15, 1909	277–284	95	76.5	85	882
July 17	Aug. 6	21	June 10, 1909	308	95	76	85.18	886.75
Aug. 16, 1909	Sept. 8, 1909	24	Jan. 28–Feb. 25, 1910	142–170	110	77	89.39	1,112.75
Apr. 25, 1910	May 31, 1910	37	July 19–Aug. 4, 1910	49–65	93	43	73.89	1,143
May 7, 1910	June 6, 1910	31	Mar. 15, 1911	282	100	59	76.62	1,042.25
May 9, 1910	June 8, 1910	31	July 19–Aug. 4, 1910	41–57	100	59	77.42	1,067
May 17, 1910	June 11, 1910	26	Feb. 5, 1911	239	100	60	79.30	943.80

OUT OF DOORS.

Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Maximum.	Minimum.	Average daily mean.	Total effective.
Apr. 13, 1906	May 25, 1906	43			93	41.5	68.73	1,106
May 5, 1906	June 8, 1906	35			93	42	72.94	1,048
June 25, 1907	July 21, 1907	27			99	63.5	81.30	1,034
Aug. 17, 1908	Sept. 9, 1908	24	May 29, 1909	262	100	64	80.85	908.40
June ?, 1910	July 9, 1910		Dec. 23–31, 1910	167–175				
Aug. 9, 1910	Sept. 4, 1910	27	Mar. 17, 1911	194	105.6	66.7	86.49	1,174.25
Aug. 11, 1910	do	25			105.6	66.7	86.5	1,087

The larva (Tables XC-XCII).—The greatest longevity of the larvæ of this species recorded by us was 335 days. This lot of larvæ hatched out June 27, 1908, and was kept in a glass tube on moist sand in the laboratory. One lot of larvæ kept in a tube out of doors lived 262 days. The incubation and larval longevity records given in Table XC are a few from a large number of records selected to illustrate the variation in these developmental periods. As may be

seen in the table, the longevity of the different lots varies greatly. We have not been able to account satisfactorily for the large differences in lots kept under similar conditions.

The shortest time in which engorgement took place was 4 days, the greatest number dropping from the host on the fourth to sixth days, while the last to leave the host dropped on the seventh day.

TABLE XCI.—*Engorgement of larvæ of Dermacentor variabilis.*

Date larvæ applied.	Host.	Larvæ dropped engorged—days following application.							Total number dropped.
		1	2	3	4	5	6	7	
July 31, 1907	Bovine	0	0	0	3	3	0	0	6
Aug. 5, 1907	...do	0	0	0	37	27	2	0	66
June 5, 1908	...do	0	0	0	5	17	24	3	49
Aug. 18, 1908	...do	0	0	0	0	0	5	0	5

Molting occurred in August as soon as the seventh day after dropping. At a mean temperature of 81° F. molting took place in 8 days, during which time a total of 306° F. of effective temperature accumulated.

TABLE XCII.—*Molting of engorged larvæ of Dermacentor variabilis.*

Date engorged larvæ dropped.	Host.	Number.	Engorged larvæ molted—days following dropping.						Total number molted.	Temperature from dropping to date first tick molted.		
			7	8	9	10	11	12		Maximum.	Minimum.	Average daily mean.
										° *F.*	° *F.*	° *F.*
Aug. 4, 1907	Bovine	3	0	0	1	1	1	0	3			
Aug. 5, 1907	...do	3	0	2	1	0	0	0	3			
Aug. 9, 1907	...do	37	9	18	1	0	0	0	28			
Aug. 10, 1907	...do	26	4	12	4	3	1	0	24			
Sept. 7, 1907	Dog	1	0	0	0	0	1	0	1			
June 9, 1908	Bovine	5	0	0	2	2	0	0	4	91.5	69	79.87
June 10, 1908	...do	18	0	0	8	4	4	0	16	91.5	69	80.50
June 11, 1908	...do	24	0	3	7	3	1	0	14	91.5	70	81.19
June 12, 1908	...do	3	0	2	0	0	0	0	2	91.5	71.5	81.39
Aug. 24, 1908	...do	5	0	0	1	2	2	0	5	90	75.5	83.27
	Total	125							100			

The nymph (Tables XCIII-XCIV).—A number of nymphs which molted on August 18, 1907, were alive March 5, 1908, but dead on March 21, 1908, the longevity of this lot being from 7 to 8 months. In another instance, however, nymphs which molted on June 18, 1908, were dead on August 4 of that year, and the last individuals of a third lot, which molted September 9, 1908, died between October 16 and October 26 of the same year. All of these lots were kept on moist sand in the laboratory.

The shortest period of engorgement recorded in our observations was 4 days. The last nymph to drop left the host on the eighth day.

TABLE XCIII.—*Engorgement of nymphs of Dermacentor variabilis.*

Date nymphs applied.	Host.	Nymphs dropped engorged—days following application.								Total number dropped.
		1	2	3	4	5	6	7	8	
Aug. 27, 1907	Bovine	0	0	0	0	2	1	1	1	5
Aug. 28, 1907	Dog	0	0	0	4	1	0	0	0	5

Engorged nymphs which dropped September 1 commenced to molt on the seventeenth day. One nymph which dropped August 28, 1909, molted on the sixteenth day after dropping. During this period the maximum temperature was 101° F., the minimum 78.5° F., the average daily mean 89.3° F., and the total effective temperature 740.8° F.

TABLE XCIV.—*Molting of engorged nymphs of Dermacentor variabilis.*

Date engorged nymphs dropped.	Host.	Number.	Engorged nymphs molted—days following dropping.										Number molted.		
			16	17	18	19	20	21	22	23	24	25	Male.	Female.	Total.
Feb. 26, 1907	Rabbit[1]	2	0	0	0	0	0	0	0	0	0	1 ♀	....	1	1+
Sept. 1, 1907	Bovine	5	0	1 ♂	1 ♂	1 ♀	2 ♀	0	0	0	0	0	2	3	5
Sept. 2, 1907	...do	2	0	1 ♂	1 ♂	0	0	0	0	0	0	0	2	0	2
Sept. 3, 1907	...do	1	0	0	1 ♀	0	0	0	0	0	0	0	0	1	1
Sept. 4, 1907	...do	1	0	0	1 ♀	0	0	0	0	0	0	0	0	1	1
Aug. 28, 1909	Squirrel	1	1 ♀	0	0	0	0	0	0	0	0	0	0	1	1
	Total	12	....	....	....	....	....	....	....	....	....	....	4	7	11+

[1] Collected from a swamp rabbit.

The adult (Table XCV).—The maximum adult longevity observed by us was 233 days. This record was made on a single female which became adult September 13, 1909. A female which was collected on an opossum May 10, 1910, lived 202 days, and one male in a lot consisting of 2 males and 3 females, which were collected on a squirrel April 6, lived 106 days. Other lots of collected individuals lived from 15 to 93 days. If a large number of freshly molted individuals were kept for longevity tests without allowing them to feed it is probable that some individuals would be found to live longer than any observed by us.

In our observations mating has been preceded by a period of feeding of from 3 or 4 to 10 or more days after attaching to a host and

has continued for a day or so only. Females have been found to reattach even when engorged to a considerable extent. Unengorged females taken from dogs to which they had attached, and on which they had probably mated, engorged as soon as 5 days. Nine days was the shortest period in which previously unattached females engorged. Morgan, however, states that females engorge in from 5 to 8 days.

During engorgement the females constantly excrete what appears to be undigested blood. The adults also void considerable excrement soon after molting from nymphs.

A male which, with a female, was placed upon an ox November 1, 1907, remained upon the host, frequently changing its position, until February 14, when it was found attached but dead. Thus it remained upon the host for 105 days from its attachment and 91 days after the female had dropped engorged. Other males have disappeared from the host on the eighth day after the females dropped.

TABLE XCV.—*Engorgement of females of Dermacentor variabilis.*

Adults applied.	Host.	Females dropped engorged.	Period of attachment.	Size engorged.
			Days.	
Nov. 1, 1907	Bovine	Nov. 15	14	13 by 9 by 5 mm.
Mar. 23, 1908	do	Apr. 1	9	12 by 9 by 5 mm.
June 19, 1908	Bovine (reattached)	June 24	5	13 by 11 by 7 mm.
Do	do	June 25	6	13 by 11 by 7.5 mm.
Do	do	June 26 (5)	7	12 by 9 by 6.5 mm. 12.5 by 9.5 by 8 mm. 13 by 10 by 8 mm. 13 by 9 by 7 mm. 13 by 10 by 7 mm.
Do	Bovine	June 27	8	12.5 by 10 by 7.5 mm.
Aug. 24, 1908 (slightly engorged).	Bovine (reattached)	Aug. 30	6	12 by 7 by — mm.
Aug. 24, 1908	do	Aug. 31	7	10 by 7 by 5 mm.
Apr. 19, 1909	do	Apr. 27	8	13.8 by 9.4 by 7.3 mm
Sept. 8, 1909	do	Sept. 16	8	Fully engorged.
Do	do	Sept. 17	9	Partly engorged.
Mar. 26, 1910	do	Apr. 11	16	One-third engorged.

LIFE CYCLE.

Larvæ may live for 335 days; they may engorge as soon as 4 days after application to a host and molt as soon as 7 days after dropping, a total effective temperature of 306° F. being required for molting. Nymphs may live for from 7 to 8 months; they engorge as soon as 4 days after attachment and may molt as soon as 16 days after dropping. A total effective temperature of about 741° F. appears to be required for this transformation. Adults may live as long as 233 days; they may engorge in 8 days (5 days ?) and commence ovipositing as soon as 5 days after dropping. As many as 7,378 eggs may be deposited. Embryonic development may be completed in 20 days, a total effective temperature of 825° F. being required.

Adults of this tick have been collected on animals in Texas at all times of the year. However, they appear to be most abundant in the spring and early summer. Nymphs have been collected on animals in considerable numbers in February, March, and April, and in one instance in August. With little doubt the immature stages are to be found on hosts nearly all the year round.

ECONOMIC IMPORTANCE.

Aside from the fact that this species occasionally attaches to man and domestic animals and often causes considerable annoyance, it is of no economic importance. The ticks are easily removed from a host and their attachment has not been known to produce any serious consequences.

NATURAL CONTROL.

The many bird and other enemies of the cattle tick undoubtedly prey upon this tick also. Dogs have been observed by us to crush them with the teeth, both when attaching and after dropping.

ARTIFICIAL CONTROL.

This species has not been found to occur in numbers except upon the dog and some wild mammals. When dogs become badly infested the ticks may be removed by washing the dogs with one of the standard tick dips. Ordinarily hand picking will suffice to keep them in check.

THE TROPICAL HORSE TICK.

Dermacentor nitens Neumann.

The common name of this species is derived from the fact that its distribution is restricted almost entirely to the Tropical Life Zone and that the horse is its principal host.

DESCRIPTIVE.

Adult (Pl. XIII, figs. 8–10, 13, 14).—Males 2.5 by 2 mm. to 3 by 2 mm. Females, unengorged, 3.25 by 1.75 mm. to 3.5 by 2 mm.; engorged, 9 by 7 mm. to 12 by 9 by 5 mm. Both sexes are reddish brown and without white markings.

Nymph (Pl. XIII, figs. 7, 11, 12).—Unengorged, about 1.33 by 0.9 mm.; engorged, 2.9 by 1.8 by 1 mm. to 3.5 by 2.2 by 1.3 mm. Color, unengorged, pale brownish yellow; engorged, dark gray. Capitulum, 0.359 mm. long (from tip of hypostome to base of emargination of scutum); scutum 0.54 mm. long by 0.641 mm. wide. The shape of the nymph, particularly when engorged, as with the engorged female, is quite typical of the species; the greatest width is at the

third pair of legs, from which the body is very noticeably constricted posteriorly.

Larva (Pl. XIII, fig. 6).—Unengorged (in balsam), 0.714 by 0.470 mm.; engorged, 1.5 by 0.9 by 0.6 mm. Color, unengorged, yellowish brown; engorged, steel-gray. Capitulum 0.205 mm. long (from tip of hypostome to base of emargination of scutum); scutum 0.290 mm. long by 0.372 mm. wide.

Egg.—The average size of 10 eggs measured was 0.565 by 0.419 mm. Color yellowish brown to brown; shining, smooth.

HOST RELATIONSHIP.

The type host of this tick, the horse, is the principal host for the species. This tick has also been taken from the ears of the mule at Brownsville, Tex., and at Tampico and Victoria, Mexico, Bishopp found it commonly in the ears of both the mule and the ass. It prefers the inside of the ears as a place for attachment. Hooker has found a number of specimens attached in the horse's mane between the ears and several to the belly. This, however, was due to the fact that the ears were literally filled with ticks so that there was no place in the ears to which they could attach. In Texas several larvæ have been taken from the ear of a goat. The tick has also been taken from the ears of the ox and of a calf. A single specimen in poor condition, but apparently of this species, was taken at Kerrville, Tex., by Mr. F. C. Pratt from a deer skin that had been removed in January. In our studies we have found them to attach to the scrotum of a bovine and develop to engorged adults.

GEOGRAPHICAL DISTRIBUTION.

(Fig. 17.)

Jamaica and Santo Domingo are the type localities for this species. In the vicinity of Brownsville, Tex., it is an important pest to horses which run in pastures; it has also been taken at Harlingen and at Corpus Christi, Tex. A single specimen which appears to be this species was collected at Kerrville, Tex., but the species has not been found during subsequent collections in that vicinity. There seems to be much doubt of the correctness of the record of this species from Arizona. The tick was found in abundance at Victoria and Tampico, Mexico, but careful search for the species failed to reveal its presence on the plateau in the central and northern parts of that country. It has been recorded from Guatemala, Panama, and Costa Rica in Central America and from Cuba, Jamaica, Haiti, Santo Domingo, and Trinidad in the West Indies. It appears to be a serious pest in Cuba and Jamaica.

LIFE HISTORY.

Observations on the biology of this species have been published by Hooker (1908) and by Newstead (1909).

The egg (Table XCVI).—The first 3 ticks the oviposition of which was recorded were collected from the ears of a horse; the next 7 were

FIG. 17.—The tropical horse tick, *Dermacentor nitens:* Distribution in North America and West Indies. The large dots show localities where the species has been collected in our investigation. The small dots indicate the probable range of the species in North America and the West Indies.

picked from the ear of a mule; and the last 2 dropped from the ear of a bovine.

The preoviposition period in the 12 ticks recorded varied from 3 to 15 days. The minimum period occurred in the case of 2 females

which dropped from a host on July 27. These ticks were kept at a mean temperature of 85.4° F. The period of deposition ranged from 15 to 37 days. The length of this period, as well as that of the preoviposition period, is materially affected by temperature, the high temperatures producing the shortest periods. The maximum number of eggs deposited by 1 tick was 3,392 in the lot of 12 females observed; the average was 2,784.

The minimum incubation period for eggs in the laboratory at a mean temperature of 85° F. was 24 days. An effective temperature of 935° F. appears to be required for incubation.

TABLE XCVI.—*Preoviposition, incubation, and larval longevity of Dermacentor nitens.*

OUT OF DOORS.

Date engorged female dropped.	Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Temperature during incubation.			
						Maximum.	Minimum.	Average daily mean.	Total effective.
1908.	1908.	1908.	*Days.*	1908.	*Days.*	°*F.*	°*F.*	°*F.*	°*F.*
Apr. 22	Apr. 29	June 5	38	Aug. 15	71	91	43	73.2	1,149.2
Do....	...do.....	June 6	39	Aug. 7	62	91	43	73.5	1,187.7
May 17	May 21	June 20	31	Aug. 14	55	93	62	79.3	1,125.3
May 18	May 26	June 24	30	Aug. 15	52	96	62	80.4	1,120.6
May 19	...do.....	June 26	32	...do.....	50	96	62	80.3	1,195
May 20	May 27	June 28	33	Aug. 19	52	96	62	80.3	1,232.5
May 22	May 26	...do.....	34	Aug. 28	61	96	62	80.3	1,268.2
May 26	June 2	July 1	30	Aug. 29	59	96	62	80.5	1,124.9

IN THE LABORATORY.

Date engorged female dropped.	Eggs deposited.	Hatching began.	Minimum incubation period.	All larvæ dead.	Larval longevity.	Maximum.	Minimum.	Average daily mean.	Total effective.
....	May 2	June 1	31	....	....	87	56	75.2	999
....	May 3	June 3	32	....	....	88	56	75.8	1,049.5
....	May 9	June 5	28	....	....	88.5	65	77.5	966
....	May 10	June 6	28	....	....	88.5	65	77.8	957
....	May 13	June 8	27	....	....	90	65	78.3	952.8
....	May 14	June 9	27	....	....	90	65	78.7	963.3
....	May 15	...do....	26	....	....	90	67	79	935.3
....	July 31	Before Aug. 29	Less than 30	Dec. 5	About 98	....	....	....	....
....	Aug. 2	...do....	Less than 28	Nov. 26	About 89	....	....	....	....
....	Aug. 6	Aug. 29	24	Nov. 26–Dec. 24	89–117	99	73	85.25	1,014
....	Aug. 9	Sept. 1	24	Oct. 26–Nov. 17	55–77	96.5	73	84.4	1,000

The larva (Tables XCVI–XCVII).—As is shown in Table XCVI, the longevity of larvæ which hatched in June and were kept in tubes under the most favorable conditions was only 71 days. All of the larvæ from eggs of females which dropped in May were dead 2 months after hatching. Seed ticks hatching from eggs isolated at daily intervals and kept in tubes in the laboratory were frequently found to die in 10 days or 2 weeks. The greatest longevity of this stage observed by us was between 89 and 117 days. This species, the cattle tick, and another species of Dermacentor (*albipictus*), which is now being studied, are the only species occurring in the United States, which, so far as known, pass both molts upon the host. As a

result of this habit great numbers of ticks reach maturity and reproduce, but fortunately there has also resulted a great decrease in the power of the larvæ to withstand periods of fasting.

As is shown in Table XCVII, larvæ may engorge and molt as soon as the eighth day after attaching to a host. The longest period from larval attachment to molting was 16 days.

The nymph (Table XCVII).—In two of the three lots recorded in Table XCVII nymphs became engorged and began molting on the seventeenth day after being applied to the host as larvæ. In the third infestation nymphs began molting to adults on the twenty-fourth day after being applied. The period from the molting of the first larvæ to the molting of the first nymph was 8 days in one instance and 9 days in the other two cases observed. In one instance the nymphal period appeared to have been only 7 days.

The adult (Table XCVII.—The mating of males and females of this species, which molted on the host on the same day, took place as soon as the second day following and was continued until the engorged females dropped. This habit appears to be similar to that of *Margaropus annulatus*. A male *Amblyomma americanum* has been found attached beneath a female of this species, the ventral surfaces being in apposition as though in copulation. The sexes remained in this relation for only a short period. Likewise males of *Margaropus annulatus australis* and *Dermacentor variabilis* have remained mated with females of the tropical horse tick for a number of days. Several females have engorged and dropped, apparently without having been fertilized. One unfertilized female remained attached from the time it molted on May 6 until May 26, when it dropped unengorged. A second unfertilized female which molted July 18 dropped August 11 when only slightly engorged.

Females have engorged as soon as 9 days after molting or 26 days after attachment to the host as larvæ. The longest engorgement period observed was 23 days after molting, or 41 days after being applied to the host as a larva. Females collected at Brownsville, Tex., in November have reattached to a host 3 days later. A slightly engorged female thus transported attached and dropped engorged 7 days later, measuring 10 by 8 by 5 mm. Newly molted females reared from engorged nymphs taken from a horse have attached to a bovine. One thus attached on December 9, 1907, dropped engorged 11 days later, measuring 10 by 7 by 4.5 mm. A second, attached at the same time, dropped after 15 days of attachment, measuring 10.5 by 7.5 by 4.5 mm.

A male has been found to remain upon a host 84 days after the first female dropped, or 99 days after attachment as a larva. At the end of this period it was found dead in the retaining bag. Upon another host a male remained for 72 days after the last female dropped, or 86

days after it had been collected from an equine and placed upon the bovine. It detached and escaped from the bag at the end of this time.

A peculiar habit which is especially noticeable in this species is that of the excretion, by the female during engorgement, of large quantities of a substance which when dry resembles coagulated blood. This habit, while particularly noticeable in the members of the genus Dermacentor, is most pronounced in this species. It is a frequent occurrence for the male to get incrusted in the excreta and, being unable to extricate himself, to perish. It is this habit of voiding large quantities of excrement that increases to some extent the economic importance of this tick.

PARASITIC PERIOD.

The parasitic cycle of three lots was followed upon bovines at the laboratory. Two of these lots were placed upon the scrotum of the host and the third in the ear.

On April 10, 1908, numerous larvæ were placed on the scrotum of a bull; 2 molted to nymphs on April 23, 2 on April 24, and 1 on April 25, or the thirteenth, fourteenth, and fifteenth days, respectively, after application. On May 4, 1 molted to a female; May 6, 1 molted to a female; and May 19, 2 molted to females; or the twenty-fourth, twenty-sixth, and twenty-ninth days after application. As no males were present the females were not fertilized and they only partially engorged. A second lot of larvæ was applied to the scrotum of a bull on April 18, 1908. They began to molt on the ninth day and molted as follows: April 27, 3; April 28, 6; April 29, 2; April 30, 1. On May 5, the seventeenth day after application, 1 nymph molted to a male, and molting continued as follows: May 6, 1 male, 1 female; May 7, 1, and from May 9 to 11, 1 molted each day, and on May 13, 2 molted, the sex of the last mentioned not being recorded. The first engorged female dropped on May 17, or 29 days after attachment as a larva. Others dropped engorged on July 18, 19, and 20; 2 on July 22, and the last on July 26, or 38 days after having attached as a larva.

A third lot of larvæ was applied to the ear of a host on July 1, 1908. They began to molt 8 days later (July 9), many having molted by the ninth day and all by the eleventh. Many nymphs were fully engorged on July 14, but did not molt until the seventeenth day (July 18), when 2 males and 2 females appeared; all had molted by the following day. Three females dropped engorged on July 27, the twenty-sixth day from attachment; a partially engorged female was crushed on July 29 and the last female was missing on August 11, after having remained mated with a male for 10 days.

TABLE XCVII.—*Summary of parasitic periods of Dermacentor nitens on a bovine.*

Date larvæ applied.	Location.	Days following application of larvæ.					
		Larvæ molted.		Nymphs molted.		Females dropped.	
		First.	Last.	First.	Last.	First.	Last.
1908.							
Apr. 10	Scrotum	13	15	24	29	Not fertilized.	
Apr. 18	do	9	16	17	26	29	38
July 1	Ear	8	11	17	18	26	41

LIFE CYCLE.

The larvæ are short lived, living only 71 days in summer under the most favorable conditions; they engorge and molt on the host as soon as 8 days after attachment. Nymphs may molt as soon as the seventeenth day after attachment or 7 days after the larvæ molt. Adults may engorge and drop as soon as 9 days after the nymphal molt or 26 days after attachment as larvæ. In summer oviposition may commence on the fourth day following dropping and as many as 3,392 eggs may be deposited. Eggs may hatch in 24 days during the summer. An effective temperature of 930° F. appears to be required for incubation.

ECONOMIC IMPORTANCE.

In the United States this tick has been found to be of considerable economic importance in the vicinity of Brownsville, Tex. In November, 1907, one of the authors (Hooker) accompanied by Mr. J. D. Mitchell visited the Carman Ranch, 7 or 8 miles north of Brownsville, where a dozen or more horses had been at pasture for a number of weeks. Several of these animals were lassoed and examined. Their ears were found to be literally filled with ticks of this species in all stages of development. The molted skins and excrement which had collected in the ears in large quantities were the source of a nauseating stench. Bishopp observed similar conditions among horses, mules, and burros at Tampico and Victoria (Tamaulipas), Mexico, during December, 1909, all stages of the tick being present at that time. He was informed that this is a troublesome pest in that region. Work animals become "touchy" about the head and sometimes refuse to be bridled. Several men stated that the ears of animals frequently suppurate extensively and that in some cases the distal half of the ear drops off.

Dr. N. S. Mayo, in the report of the Cuban Experiment Station for 1907, page 25, says: "These ticks sometimes collect in horses' ears in such numbers as to cause the ears to lop and the screw-flies attack the ear and permanently disfigure the animal." The filth and decay-

ing animal matter must frequently result in suppuration and extensive proliferation, as well as forming a suitable place for the breeding of screw-worms.

NATURAL CONTROL.

No natural enemies of this tick have been recorded in the United States. Cold appears to have a decided effect on both adults and larvæ. At Dallas, Tex., during the early winter of 1909, when a minimum temperature of 20° F. was reached, many engorged females were killed and the few eggs deposited by others failed to hatch.

ARTIFICIAL CONTROL.

This tick is undoubtedly the easiest species to deal with that occurs in the United States on account of the short life of the larvæ and the ease with which the ticks may be destroyed on the host. The frequent application of oil to the ears will assist in keeping horses free from them. One of the authors is informed by men at Tampico, Mexico, that kerosene and lard are frequently applied to the ears of horses and mules in that section in order to destroy the ticks. Reinfestation was said to take place again very soon, however, as no effort is made to prevent the dropping of the engorged females or to starve the larvæ. The keeping of stock from an infested pasture for four months in summer will probably be sufficient to insure the starvation of the seed ticks.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 107.

L. O. HOWARD, Entomologist and Chief of Bureau.

RESULTS OF THE ARTIFICIAL USE OF THE WHITE-FUNGUS DISEASE IN KANSAS:

WITH NOTES ON APPROVED METHODS OF FIGHTING CHINCH BUGS.

BY

FREDERICK H. BILLINGS,

Associate Professor of Botany and Bacteriology,

AND

PRESSLEY A. GLENN,

Assistant Professor of Entomology, University of Kansas.

ISSUED DECEMBER 21, 1911.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 17, 1911.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "Results of the Artificial Use of the White-Fungus Disease in Kansas: With Notes on Approved Methods of Fighting Chinch Bugs," by Frederick H. Billings, associate professor of botany and bacteriology, and Pressley A. Glenn, assistant professor of entomology, University of Kansas.

The chinch-bug situation having become serious in Kansas, provision was made by the University of Kansas for the distribution of insects infected with the white fungus, *Sporotrichum globuliferum.*

The results of this work are embodied in the following pages, and I recommend the publication of this manuscript as Bulletin No. 107 of this bureau.

Respectfully,

C. L. Marlatt,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFATORY NOTE.

The chinch-bug situation having become serious in Kansas in 1909, provision was made by the University of Kansas for the distribution of diseased insects during the season of 1910 in accordance with the plan inaugurated by Dr. F. H. Snow during the nineties. The efficacy of this method of combating chinch bugs, however, has been questioned, not only by local investigators who gathered the field data for Dr. Snow's later reports, but by observers in other States, where, in most instances, the practice of distributing diseased bugs has been discontinued. While the demand of Kansas farmers for diseased bugs was granted, steps were taken to conduct an investigation of the problem of artificial distribution, not from the standpoint of proving or disproving Dr. Snow's theories as carried out in the nineties, but rather from the standpoint of practicability under present conditions.

The investigation was placed in charge of the writers, who began work in January, 1910, for the purpose of definitely settling the question as to the utility of continuing the work of artificial infection. It was felt that the seriousness of the situation to the farmers merited a stand that was based on many carefully collected data, so that future efforts might be urged along lines shown to be most efficient.

The writers of this bulletin wish to express their appreciation to Chancellor Frank Strong, whose continued interest in the investigations made them possible; to Profs. Stevens and Hunter for helpful suggestions; to Prof. Barber for the report of his work on chinch-bug inoculation; to Messrs. Leslie Kenoyer and Otto Opollo for their faithfulness in conducting experiments and taking observations near their respective homes; and to Messrs. E. O. G. Kelly, L. A. Kenoyer, and W. C. Bower for collecting weather data.

FREDERICK H. BILLINGS.
PRESSLEY A. GLENN.

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Historical Summary of Chinch-Bug Diseases.

Since Dr. Snow, in his First and Sixth Reports of the Experiment Station of the University of Kansas, has given a somewhat extensive account of the chinch-bug disease prior to 1896, only a brief historical summary is deemed necessary in this bulletin.

Three chinch-bug diseases have engaged the attention of entomologists—a bacterial disease and two fungous diseases. What was at first supposed to be a bacterial disease was, on further investigation, ascertained to be only a normal condition in healthy bugs, so the two fungous diseases are the only true ones which have received attention.

One of the fungous diseases is due to a parasitic fungus, known to science as *Empusa aphidis*, and popularly known as the gray fungus, since it envelops the dead bug in a gray covering; the other is due to another parasitic fungus, known to science as *Sporotrichum globuliferum* and commonly known as the white fungus, since it envelops the dead bug in a white cottony mass. The latter is of special interest to us since it is the one which has been under investigation in Kansas.

The chinch bug was first noticed in North Carolina in 1783.[a] In the Mississippi Valley it has been known since 1823.[b] Since 1840 it has been under constant observation in Illinois and other States. It proved such a destructive pest from the first that entomologists have diligently sought for effective remedies by which its depredations could be avoided.

The first evidence of disease among chinch bugs was noted by Dr. Henry Shimer at Mount Carroll, Ill., in 1865.[c] According to Dr. Shimer's notes, this outbreak was first noticed on low creek-bottom land, spreading gradually to the higher localities. The disease attacked both the old and the young, and was at its maximum during the moist, warm weather that followed the cold rains of June and the first part of July of that year. So complete was the destruction of the bugs that he wrote on August 8:

> Scarcely one in a thousand of the vast hosts of young bugs observed in the middle of June yet remain alive, but plenty of dead ones may be seen every-

[a] Fitch's Noxious Insects of New York, 1865.
[b] Dr. Forbes's Insect Life, vol. 1, No. 8, p. 259.
[c] See Bibliography, p. 54.

where lying on the ground, covered with the common mold of decomposing animal matter, and nothing else, even when examined by the microscope. Even of those that migrated to the cornfields a few weeks ago in such numbers as to cover the lower half of the cornstalks, very few are to be found remaining alive; but the ground around the base of the corn hills is almost literally covered with their moldering, decomposing bodies. This is a matter of so common occurrence as to be observed and often spoken of by the farmers. They are dead everywhere, not lying on the ground alone, but sticking to the blades and stalks of corn in great numbers, in all stages of development.

Entomologists were slow to accept Dr. Shimer's theory of an epidemic disease. Walsh and Riley ridiculed the idea, and Le Baron six years later declared that he knew of no predaceous parasitic enemies of the chinch bug. Later observations, however, confirmed the accuracy of Dr. Shimer's observations.

Evidence of disease among chinch bugs was not again reported until 1882, when Dr. S. A. Forbes, of Illinois,[13] and Prof. Popenoe, of Kansas,[11] both reported localities in their respective States in which the bugs were dying with a fungus disease which embedded the dead bugs in a growth of white mold.

In August of the same year Dr. Forbes discovered what he thought was a bacterial disease due to a bacillus which he found in great numbers in the alimentary canal of dead bugs; [10] but after a thorough investigation, which extended through several years, he ascertained that the presence of the bacillus was a normal condition in the alimentary canal of healthful chinch bugs,[63] and the theory of a bacterial disease was abandoned.

The fungus disease noted by Dr. Forbes and Prof. Popenoe was what is commonly known as the gray fungus, *Empusa aphidis*. What fungus was responsible for the disease among the bugs reported by Dr. Shimer can not be ascertained. The white fungus had not yet been detected. This fungus was first observed by Dr. Forbes in Clinton County, Ill., July 7, 1887, and again on August 7, 1888.[36] [54]

For more than a year this fungus affection was not found among chinch bugs, although a close watch was kept for it, but August 7, 1888, it was seen at Flora, in Clay County, fastening dead bugs to leaves of corn.

Almost simultaneously it was reported from Minnesota,[32] Iowa,[27] Ohio, and Kansas.[35]

It is worthy of note that no evidence of disease among chinch bugs was noted for about 80 years after the chinch bug became known as a serious pest, and it was 100 years after its first appearance that the white fungus was definitely recognized. It is also all the more remarkable in view of the prevalence of the disease over such a wide area at this time and during the years following. If these diseases were present among the bugs from the first, it seems strange that they were not detected earlier, and if they were in the process of introduction it seems strange that almost simultaneously they should be so plentiful in so many different, widely separated localities. It

is probable that they were present from the first, but because of the fact that they are so dependent upon the abundance of their host and upon favorable weather conditions they are not conspicuous except at intervals when conditions are just right.

In the years immediately following the discovery of the white fungus much attention was given to the investigation of chinch-bug diseases.

Dr. Lugger, of Minnesota, was the first to attempt to disseminate the disease by the distribution of diseased bugs. In October, 1888, he sent diseased bugs to various localities, and the experiment was apparently successful, as the bugs in these localities were found to be dying with the disease a little later. But the disease spread so rapidly that Dr. Lugger was led to suspect very strongly that the spores of the disease were already in these localities and that he had only reintroduced them, the spread of the disease being due to the spores that were already there rather than to the spores which he introduced.[32] [33]

Dr. Snow's observations and experiments in Kansas began in 1888 and extended through the season of 1896. In 1888 the chinch bugs disappeared from some of the eastern counties of the State during the months of May and June, and Dr. Snow expressed the belief that they were carried off by an epidemic.[35] Experimenting with the gray fungus, *Empusa aphidis*, he found that the disease could be communicated from diseased bugs to healthy ones by confining healthy bugs with the diseased ones. He also sent some diseased bugs to farmers and to agricultural experiment stations in Nebraska, Iowa, Missouri, Minnesota, Michigan, Indiana, Illinois, and Kentucky. The reports received from those who received the diseased bugs were very encouraging.[66]

In 1890 chinch bugs in Kansas were very scarce, having been very generally exterminated in 1889.

In 1891 the legislature established an experiment station at the University of Kansas "to propagate the contagion, or infection, that is supposed to be destructive to chinch bugs, and furnish the same to farmers free of charge, under the direction of the chancellor, F. H. Snow."

During this period between 40,000 and 50,000 packages of the fungus were sent out to farmers, and extensive experiments were carried on in the laboratory and some in the field; the life history of the white fungus was worked out, and the best means of propagating it in large quantities ascertained. Observers were sent out from the station at various times to make observations in the field. The reports of these observers in 1891 and 1892 were very favorable, but in succeeding years the results of the observations were less favorable and brought to light the probability that the fungus was widely distributed naturally, since it seemed to be the rule rather than the

exception that the fungus was working as effectively in fields where none had been introduced as in fields where it had been artificially distributed. The fungus was found in every locality where the inspectors made observations. In commenting on this fact, Dr. Snow said:[86]

Whether this widely extended natural presence of the Sporotrichum was the result of the general introduction of the infection throughout the State, in 1894, from the laboratory of this station it would not be possible with certainty either to affirm or deny.

A full account of Dr. Snow's work will be found in his six reports of the experiment station of the University of Kansas for the years 1891, 1892, 1893, 1894, 1895, and 1896. The following is taken from his last report:

RESULTS OF EXPERIMENTS FOR 10 YEARS, 1888–1897.[87]

1. Chinch bugs in any of their stages of development scarcely run the slightest risk of death on account of heavy rains, even when these are of long duration. They are inconsiderably affected by extremes of heat and cold.

2. We know of no contagious bacterial disease of the chinch bug.

3. There are two parasitic, contagious, fungoid diseases that kill chinch bugs, namely, *Sporoirichum globuliferum* ("white fungus") and *Empusa aphidis* ("gray fungus").

4. These two diseases show their greatest virulence where the ground is damp and shaded from the direct rays of the sun and the air is humid.

5. We do not know to what extent the spores of these diseases are normally present in any given region. When they are present, whether naturally or artificially introduced, and the weather conditions are as given above, and the bugs are massed together, an outbreak of the diseases will occur. The number of chinch bugs killed in any field is approximately proportionate to the number of bugs in the field.

6. Sporotrichum can be artificially communicated to healthy chinch bugs. (*a*) It attacks bugs of all ages, but the older the bug the more easily does it succumb. (*b*) Bugs of any age that have been weakened from any cause, or injured, fall more easy victims to the disease than do those individuals that are in perfect condition. (*c*) The adults of the second brood, which, in the ordinary course of events, winter over and lay the eggs for the brood of the succeeding spring, are much more successful in resisting the disease than are the adults of the first brood. (*d*) The fungus is not active in winter, and, though it be present with the bugs in their winter quarters, they do not die of it, even though the winter be as mild and humid as was that of 1895–96.

The chinch bug seemed to have been almost exterminated in 1896 and there has not been any widespread outbreak since until the last two years, and hence little opportunity to investigate the practical value of the use of Sporotrichum until this year. Many requests for the fungus were received at the university last year, but no provision was made by the university to supply it until this year.

WORK IN OTHER STATES.

The method of combating chinch bugs by the artificial distribution of infection has been extensively used in other States, but in most cases the practice has been abandoned.

Dr. Lugger, who first attempted to disseminate the disease by means of distributing diseased bugs in 1888, adopted the plan again in 1895. In the First Annual Report of the State Entomologist of the State Experiment Station of Minnesota for the year 1895, he says:

Judging from the large number of letters, the writers were well pleased with the results of spreading spores among chinch bugs. * * * Of course it would be folly to claim that the disease was always spread by the introduction of such spores, and it is also possible that it would appear simply because the climatic conditions were in its favor. Whatever may be the reasons for its appearance, so many farmers believe in the effectiveness of introducing spores causing the disease that the State can well afford to continue this work.

However, the practice has been abandoned in Minnesota. Prof. F. L. Washburn, State entomologist, in Bulletin No. 77, Agricultural Experiment Station, 1902, says:

We do not know of any profitable means of killing the chinch bugs in the grain at present. In this connection we will say that the sending out of diseased chinch bugs has been abandoned, it having been found that the results were not sufficiently practical.

Dr. S. A. Forbes, who first definitely recognized the white fungus in 1887, began an extensive series of experiments with this and also the gray fungus, which lasted till 1896. The results of his investigations were not such as to lead him to recommend the use of the fungous diseases as a means of combating chinch bugs, although he was not ready to declare the method a failure. By isolating bugs sent in by farmers, he found that the disease developed among a large percentage of them without their being inoculated, and thus was led to conclude that the disease was very generally distributed naturally. In a series of field experiments he found that the disease was as prevalent in fields in which the fungus had not been introduced as in the fields in which it had been thoroughly distributed. Accounts of these experiments are recorded in the Sixteenth, Seventeenth, Eighteenth, Nineteenth, and Twentieth Reports of the State Entomologists of Illinois, 1888–1896. In the Twentieth Report he says:

Whether the fungi of contagious diseases can be artificially made use of to hasten or intensify the serviceable effect of favorable weather with a frequency or to an extent to make this procedure economically worth while, I am not yet prepared to say. The methods of distributing these fungi in the fields have hitherto been too crude to make their substantial failure conclusive as to the whole subject. It now seems quite clear that they can be at the best only used as a secondary to other measures, especially the midsummer measures described in the third article of this report. If applicable at all, however, they can be brought to bear at a point now entirely defenseless, and it seems the duty of American economic entomologists to spare no pains to investigate to a final and indisputable conclusion which promises so much as a remote possibility that the chinch bug may be attacked even to occasional advantage after it has settled itself in fields of small grain.

In Nebraska the fungus was used extensively in 1893, 1894, and 1901, but in the outbreaks of 1909 and 1910 the fungus was not recommended. To those asking for the fungus a circular was sent, which says in part:

It seems that the usefulness of this fungus disease as a method of destroying chinch bugs has been greatly overestimated by the farmers, since the experiments with it show that it spreads only when the weather conditions are just right—that is, when the temperature is somewhere between 70° and 80° F., and the air is very humid, and when bugs are massed in sufficient numbers that they come in contact with each other. When such conditions exist, the disease spreads rapidly and destroys the bugs very effectively, but under other conditions, especially in dry weather, the disease is quite ineffective. It is because of this extreme unreliability of the chinch-bug fungus disease, and its failure to spread when most sorely needed, that we have come to regard it as more of a detriment than a benefit in many cases, since it causes the farmer to place confidence in an unsafe measure to the neglect of more practical, though also more laborious, means of control.

The fungus was also used in Missouri, but has been discarded. Prof. J. M. Stedman[a] says:

A great many people send in to this office in the spring of the year for the chinch-bug disease, with the idea of scattering this disease about the fields of wheat and killing the chinch bugs infesting them. It is a fact that under certain climatic conditions this chinch-bug disease * * * will kill a great number of chinch bugs. But from seven years' experience with this disease in the wheat fields throughout the State of Missouri I am firmly convinced that the artificial use of this disease by the farmers of Missouri does very little, if any, good. * * * In the first place the chinch-bug disease is a natural one, found in nature, and is not an artificial one. * * *

* * * If the chinch bugs are in large numbers and the weather is hot and very moist, these spores will germinate on the bugs, and the fungus plant will kill them in great numbers. But if the weather is hot and dry, or too cool, although it may be moist enough, then the spores will not germinate, and no agriculturist has the power to bring about the proper conditions in his wheat or cornfield that will enable them to germinate. * * *

* * * I wish to say that it is very doubtful whether there is a wheat field or a cornfield in Missouri that does not naturally contain spores of this disease. I have been impressed with this fact every summer, because almost invariably, when the person applying for the chinch-bug disease sends to this office living chinch bugs that have been placed, as they should be, in a tin box containing no dirt, but some green vegetable matter, as for instance, pieces of green corn, wheat, or grass, and the box closed up as it should be, perfectly tight, thereby generating moisture in the box from these green vegetables, that by the time these bugs reach me the box contains more diseased fungus-covered bugs than we return; thus showing that the spores were already there in his field. * * * Knowing these facts, I can do no other than to conscientiously advise the farmers of Missouri not to trouble themselves with obtaining and scattering this disease about their fields, but to rely entirely, as they will ultimately have to do, upon nature to bring about the proper climatic conditions for the development of this disease in their fields.

[a] Bulletin No. 51, Agr. Exp. Sta., University of Missouri, July, 1902.

Prof. F. M. Webster was one of the first to interest himself in the investigation of the fungus. As a special agent of the United States Department of Agriculture, located at La Fayette, Ind., he conducted some experiments which showed that moisture and a large number of bugs are essential factors in the successful propagation of the disease.[38] Later, as State entomologist of Ohio (now connected with the U. S. Bureau of Entomology), he experimented with the fungus in Ohio in 1895 and 1896. As 1895 was a dry season the fungus proved ineffective; but in 1896 the weather conditions were favorable, and Prof. Webster states:[90 93]

> I have always held to the opinion that the parasitic fungus *Sporotrichum* globuliferum could only be used in a manner to effect relief to the farmers during wet seasons and where there was a superabundance of host insects * * *. This year (1896) I can say with all conditions favorable, *Sporotrichum globuliferum* has done all that Dr. Snow or any other entomologist claims for it, but under conditions as adverse as these have been favorable the results will prove quite the reverse.

It would seem that Prof. Webster's subsequent observations have not materially changed his views; for he states in November, 1909:[a]

> As the fungus has many other host insects, it is probably present to a greater or less degree throughout the country every year. There is no doubt that during wet weather considerable benefit may be derived from the artificial cultivation and application of this fungus, but its efficiency is very dependent upon this meteorological condition, and, as has already been shown, chinch bugs develop in greater abundance in dry seasons. It will thus be seen that only during unusual seasons, that is to say, seasons that have been very dry while the chinch bugs were hatching from the egg, but wet afterwards, can satisfactory results be expected from this measure.

Thus it appears that the use of the fungus has not come into general use as a means of combating the chinch bug. Its use has been abandoned in nearly every State that has given it a good trial. Only three States sent out fungus during that season—Oklahoma, Ohio, and Kansas. Dr. Gossard, of Ohio, questions very seriously the wisdom of sending out the fungus and our investigations in Kansas this season, as the report shows, have made it certain that in Kansas at least the artificial distribution of the fungus is unnecessary. Its failure to come into general use may be ascribed to the following reasons:

1. The disease proves effective only during unusually wet seasons and when the bugs are very plentiful.
2. The disease is quite generally present in the field naturally.
3. Dependence on the fungus leads farmers to neglect other more practical means of control.

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[a] Circular No. 113, Bur. Ent., U. S. Dept. Agr., 1909.

Outline of Work against the Chinch Bug Carried on in Kansas during 1910.

Owing to the presence of chinch bugs in destructive numbers over a considerable portion of the State in 1909, many requests were received for diseased bugs. The demands became so insistent that the regents of the University of Kansas made provisions for supplying the fungus to all applicants during the season of 1910. Following the methods used by the late Dr. Snow, a package of diseased bugs, accompanied by the necessary literature, was mailed to each applicant. The mailing list was primarily for residents of Kansas, but a number of farmers in Oklahoma were supplied with the fungus.

The literature consisted principally of a four-page folder, which contained, besides information for the use of the fungus, other information which was designed to enable the farmers to make intelligent observations in their own fields and to avail themselves of other methods of fighting chinch bugs.

It was understood that many authorities do not advocate the artificial use of Sporotrichum; still, in the absence of conclusive evidence to prove its impracticability, the recommendations of Dr. Snow in his last report were followed, with the hope that in the face of a threatened chinch-bug epidemic some good might result.

At the same time, however, provision was made for an investigation in order to determine definitely whether or not artificial infection accomplishes results sufficient to justify the labor and expense involved.

Work began early in 1910, some months before any infection was sent out. It was necessary to determine early which portions of the State were suited for carrying on experiments, judging from the number of bugs, and the extent of the distribution of the fungus naturally in the soil. Data as to the distribution of the fungus were regarded as more nearly conclusive if obtained before artificial distribution began.

No Sporotrichum had been distributed in Kansas since Dr. Snow distributed it from 1891 to 1896. Dr. Snow's reports show that the fungus was very generally present in the fields in 1895 and 1896, and on that account results derived from its artificial distribution were of doubtful benefit. This was thought to be a very favorable time for determining if the fungus had meanwhile maintained itself in the fields. Whether or not the fungus found in the soil at that time was the result of that sown by Dr. Snow years ago is, however, not pertinent to the problem, since the problem concerns itself with a plan of action for the present and future.

In comparing the First Annual Report of Dr. Snow for 1891 with the last one for 1896, we find statements which would lead us to believe that the artificial distribution of the disease had at least the

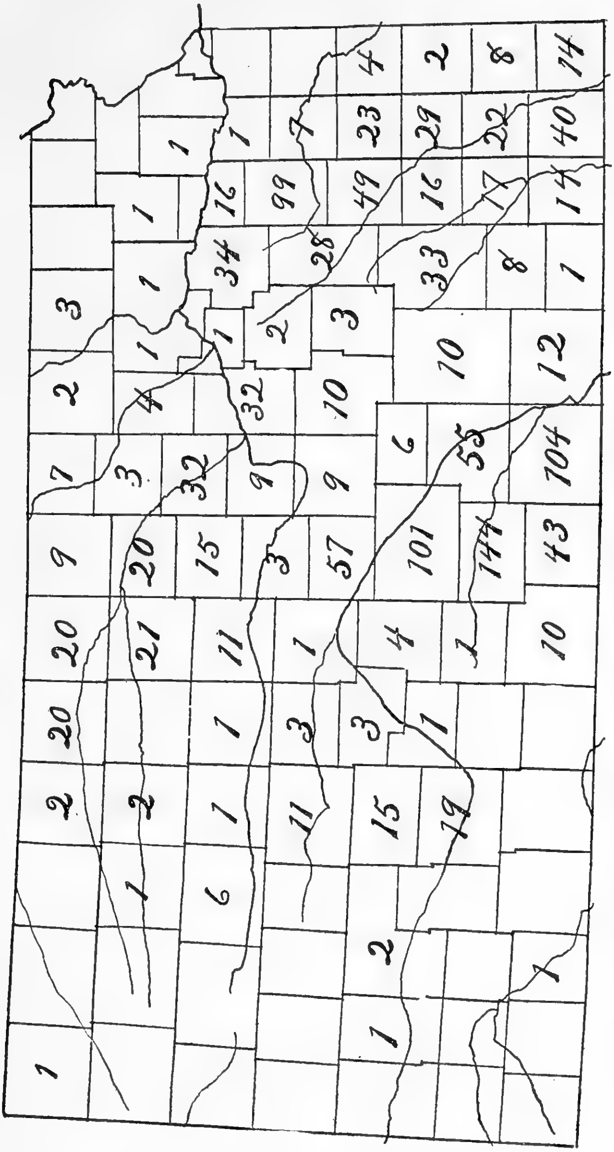


Fig. 1.—Map of Kansas showing the number of packages of diseased chinch bugs sent out in 1910 by the University of Kansas to the different counties in the infested area. (Original.)

effect of increasing the amount of Sporotrichum, even if we doubted its first introduction into Kansas in the nineties.

In the report of 1891 we read:

It must be remembered that these contagious diseases of the chinch bug are naturally present in certain ortions of the Mississippi basin during every

year, and become epidemic over large portions of this area in occasional years. The object of my experiments has been to artifically introduce the disease at times when they are not naturally raging in the fields. It was found in 1891 that there was no evidence of a natural existence of the three diseases in any part of the State of Kansas. This statement is abundantly substantiated by the detailed report of my field agent. Mr. Hickey, and by the reports of many farmers.

In his final report Dr. Snow makes this comment:

While no such general epidemic of Sporotrichum was noted in this year (1896) as occurred in 1895, yet the disease seemed present in those parts of the State visited, wherever favorable conditions existed, and in the fields, whether artificially infected or not.

It was therefore doubtless true that in the later years of Dr. Snow's campaign many spontaneous outbreaks occurred, and that conditions were perhaps not widely different from what they are to-day. Owing to a lack of scientific data, however, there is room for doubt as to the absence of Sporotrichum from Kansas soil prior to the recorded observations in 1891.

The investigations summarized in this paper had chiefly to do with the following problems:

1. Extent to which the white fungus disease of the chinch bug is naturally present in Kansas soil.
2. Practicability of artificial infection of fields in which the fungus disease is found to be naturally present.
3. Practicability of artificial infection of fields in which the fungus disease is shown to be scarce, or at least ineffective.
4. Experiments with barriers and insecticides.

Among other matters considered were (1) laboratory methods of propagating Sporotrichum; (2) artificial inoculation of chinch bugs with spores.

Natural Distribution of Sporotrichum in Kansas.

In any investigation to determine the efficacy of artificial infection of a field with a parasitic fungus, the presence or absence of the fungus is one of the first points to be determined. If its absence be proved, a widespread persistent application of the infection might result in a considerable mortality of bugs, provided, of course, they are numerous enough to spread the contagion among themselves; but if the presence of the fungus is shown to be general, the problem resolves itself into that of attempting to improve natural conditions by artificial ones. Theoretically, at least, such a thing would be possible, but its practicability must be determined by actual experiment under a variety of conditions. It would have to be shown that enough bugs, beyond what naturally would have died, succumbed to the artificially sown fungus to make the effort worth while.

STERILE JARS FILLED WITH SOIL AND CHINCH BUGS, SHOWING DISEASED BUGS RESULTING FROM A SPONTANEOUS OUTBREAK IN THE JAR. (ORIGINAL.)

The white spots in the jars are fungus-covered bugs.

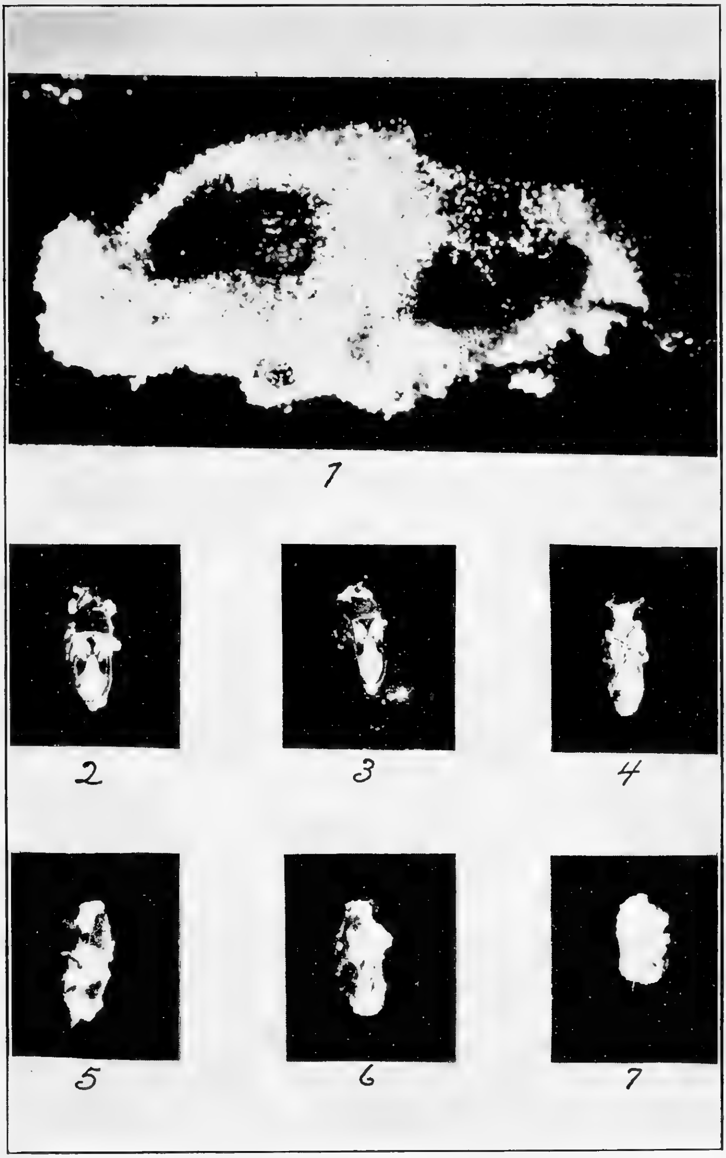


FIG. 1.—CHINCH BUG ENVELOPED IN GROWTH OF THE WHITE FUNGUS SPOROTRICHUM GLOBULIFERUM. FROM PHOTOMICROGRAPH ENLARGED X 22. (ORIGINAL.)

FIGS. 2-7.—DEAD CHINCH BUGS, SHOWING VARIOUS DEGREES OF ENVELOPMENT IN THE WHITE FUNGUS. FROM PHOTOGRAPHS ENLARGED X 7. (ORIGINAL.)

A spontaneous outbreak of the fungus in a field into which no fungus had been introduced would imply its natural presence there; and, conversely, its natural presence there would imply that a spontaneous outbreak would be possible, if given proper conditions. Hence it was determined to visit representative counties distributed through the infested area, and by examination of fields taken at random ascertain to what extent Sporotrichum is present in Kansas soil.

Natural Presence of Sporotrichum among Chinch Bugs during Hibernation.

As conditions for the development of the chinch-bug disease were not favorable while the bugs were in hibernation, partly because of the cold or cool dry weather that prevailed and partly because of the resistant state of the insects, it was necessary to collect them and bring them into warm, moist surroundings, where, with increased activity, without food, their vitality would be diminished sufficiently for them to succumb to the attack of the disease.

The type of collecting jar adopted was an 8-ounce square bottle with wide mouth and metal screw top lined with cork. This was light in weight and packed well in a carrying case. Before taking a lot of bottles from the laboratory they were thoroughly sterilized in an autoclave. The tops were left loose during sterilization and then screwed down tightly upon removal, while hot, from the sterilizer.

After placing a number of bugs and a small quantity of earth in a bottle, by the use of sterilized tools, the lid was screwed down tightly and not removed until the bugs were dead, unless the soil in the bottle was too dry, in which case a little water was added, either from a near-by source in the field or else in the laboratory. If in the laboratory, precautions were taken against exposing the contents of the bottles to contamination. The tops were loosened and lifted on one side only, and then just enough to permit the entrance of a sterile pipette, filled with sterile water. By working expeditiously no more danger of contamination from the air resulted than in making transfers from one culture medium to another.

The favorite places for hibernation on the part of the chinch bugs, apparently, were the stools of the prairie grass, *Andropogon scoparius*. The grass was uprooted and some of the bugs placed in bottles by the use of sterile lifters. Several bottles of bugs, together with a portion of the surrounding earth, were collected in at least one locality in each county visited.

It was desired to ascertain if a spontaneous outbreak of the fungus could be obtained among the incarcerated bugs. Since, under the natural conditions to which the bugs were subjected in the bottles,

there was a possibility that the proper conditions might not be secured in some of them for the fungus to develop, the uncertainty was eliminated by having a number of bottles from each locality. Sporotrichum appeared in most of the bottles (see Pl. I), though its occurrence in but one of a series was sufficient to establish the certainty of its presence in the locality from which the collection had come. In some of the bottles no Sporotrichum developed. This was generally due to an excess of moisture which caused bugs to die before the Sporotrichum had time to make its presence manifest.

The chinch bugs in the bottles generally showed remarkable powers of endurance, as they were without food yet in warm surroundings. Some were found still crawling more than two months after collection and long after observations were taken. Some continued to live for this length of time with the Sporotrichum present and projecting conspicuously from dead bugs (see Pl. II) over which they frequently crawled.

Thirty-two counties in the infested area of Kansas were definitely shown to contain the white-fungus disease among the chinch bugs before egress from their winter quarters, during the latter part of March.

The first package of diseased bugs was sent out April 7 by the Kansas State Agricultural College at Manhattan. Five days later the University began its distribution of diseased bugs. It is therefore evident that Sporotrichum was present naturally in the localities examined and only needed the proper climatic conditions to break out spontaneously in the fields.

Natural Presence of Sporotrichum in Wheat Fields and Cornfields during the Spring and Summer of 1910.

Spontaneous outbreaks.—The chinch bugs left their winter quarters the last week in March, but owing to the dryness and coolness of April, no diseased bugs were found in the fields until late in the month. In the meantime the collecting of bugs and testing for the presence of the fungus continued. Later, when fungus-covered bugs were present in the fields, they were considered as direct evidence of its natural distribution, provided artificial distribution had not been resorted to.

Observations on the presence of Sporotrichum among chinch bugs in grain fields occupied the months of April, May, and June. During this time 27 additional counties were shown to contain the fungus. Summing up the work on the natural distribution of the fungus disease, it was found that 59 counties, which include most of the infested area of Kansas, showed evidence of its presence. Six counties, four of which were on the western edge of chinch-bug distribu-

tion, where excessive drought or else scarcity of bugs constituted the conditions met with, failed to show presence of Sporotrichum. Two counties, on the northeastern border, because of great scarcity of bugs, also failed to show signs of fungus. A few counties situated among

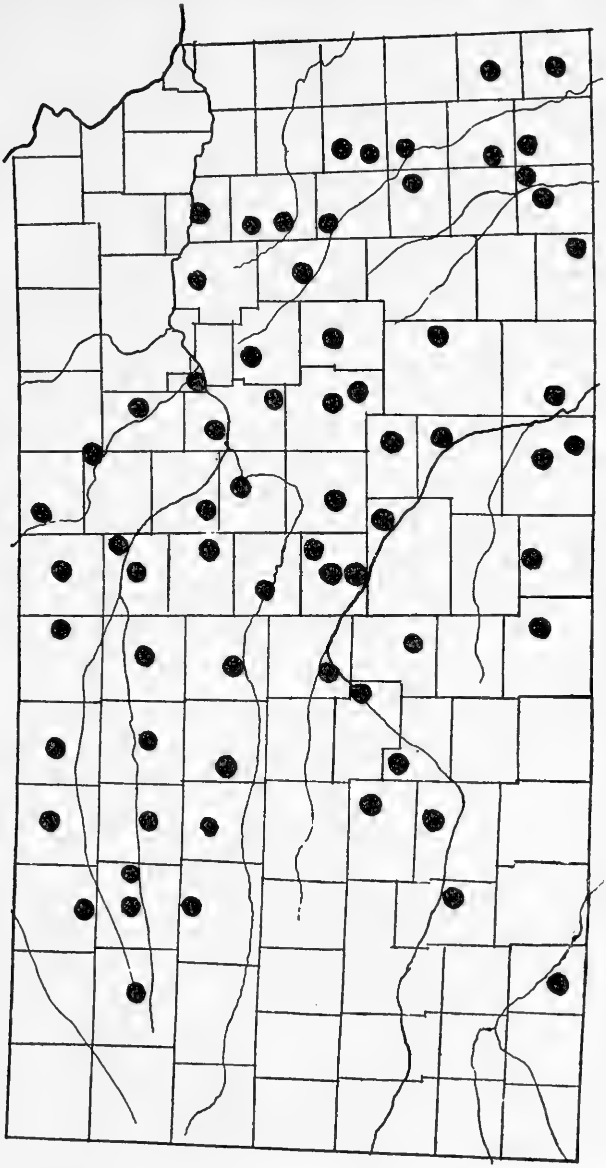


FIG. 2.—Map of Kansas, showing all the localities where Sporotrichum was found as a natural infection. (Original.)

others in which Sporotrichum was observed probably contained it, but, as they were not visited, no direct evidence was obtained. Granting its absence in such localities in 1910, however, it would be but a short time, owing to migration of the chinch bugs, before

spores from the adjacent counties would be carried over into every field where they might alight.

As will later be shown, Sporotrichum is not dependent on chinch bugs for hosts, but may live on other insects. There is hardly any question as to the presence of the fungus in the soil generally.

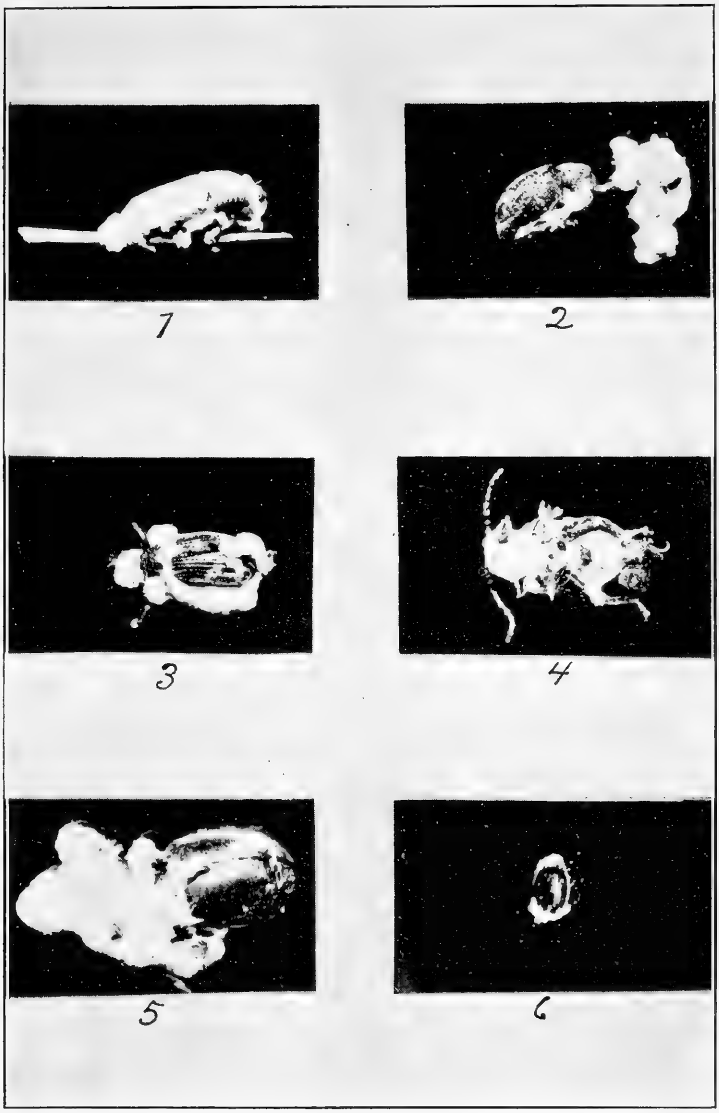
Maintenance of Sporotrichum in the soil.—From the ease with which Sporotrichum is cultivated in the laboratory at room temperature with dead organic substances as culture media, it is possible that it propagates itself, at times, saprophytically in the soil. It is not dependent, however, either on dead organic matter or on living chinch bugs, but may live as a parasite on other insects, some of which are present in Kansas as permanent fauna. Various writers from widely separated localities have reported Sporotrichum on insects other than chinch bugs. While making no attempt to search for the fungus on other than chinch bugs, the writers noticed insects from time to time displaying the characteristic Sporotrichum growth. A list of them is given below.

Insects upon which Sporotrichum has been Found.

Three common snout beetles, *Trichobaris texana*, *Conotrachelus erinaceus*, and *Anthonomus fulvus* (Pl. III, figs. 1, 2, and 3); a common flea-beetle, *Disonycha triangularis* (Pl. III, fig. 4;) a very common lady-beetle, *Hippodamia convergens* (Pl. III, fig. 5); a minute beetle of the genus *Olibrus* (Pl. III, fig. 6); and three true bugs belonging to the same order (Hemiptera) as the chinch bug, one a rather rare insect, belonging to the family Phymatidæ, the species undetermined, and the other two common forms, *Microtoma carbonaria* and *Coriscus ferus* (Pl. IV, figs. 1, 2, and 3), and two unidentified larvæ (Pl. IV, figs. 5 and 6), and many common pentatomids.

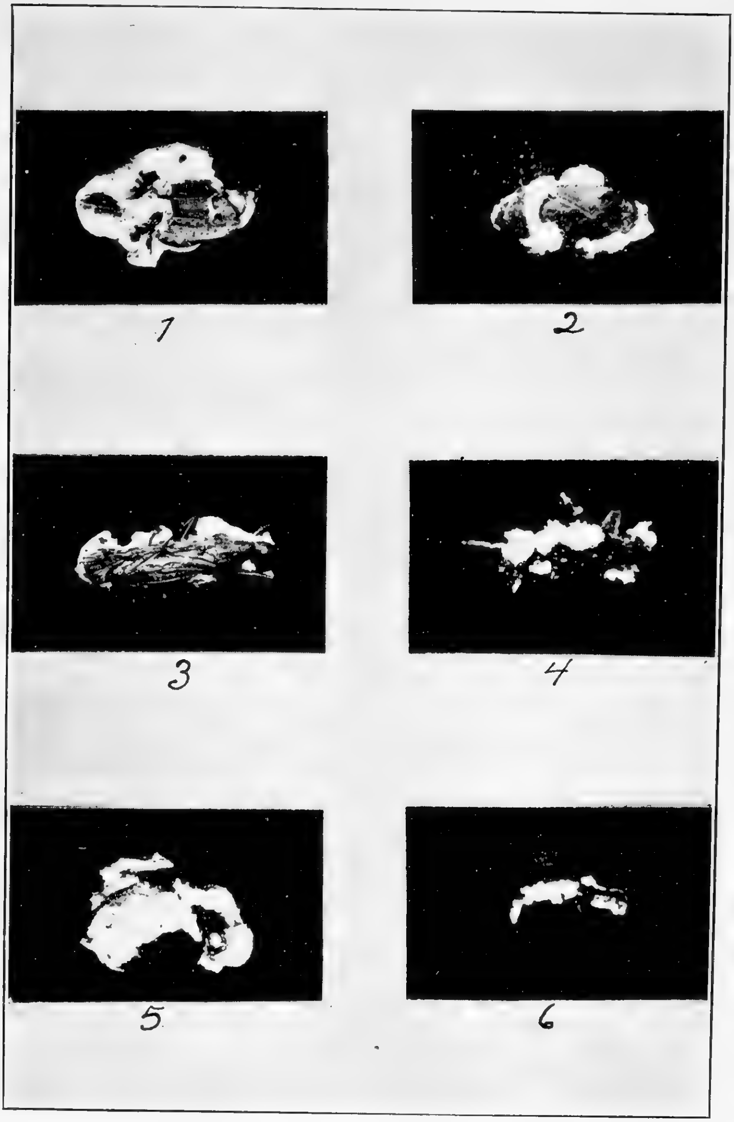
Natural Distribution of Sporotrichum in the Soil and its Relation to Artificial Infection.

The general distribution of Sporotrichum naturally in the soil might affect the artificial use of the fungus in one of two ways—by rendering it unnecessary, or by making it more effective. In the former instance a spontaneous outbreak would occur, which, if conditions were right, would be of such magnitude that, whatever man might do in the way of artificially distributing fungus spores, nothing appreciable would be added to the results; or, given unfavorable conditions with a slight spontaneous outbreak, or none at all, artificial infection would not measurably spread the disease. In the second instance when there is already a spontaneous outbreak of considerable size, artificial infection might increase this to an epidemic that would end in a high percentage of mortality among the bugs. Other



VARIOUS INSECTS KILLED BY FUNGUS DISEASES. NO. 2 IS ISARIA SP., THE OTHERS SPOROTRICHUM. (ORIGINAL.)

Fig. 1.—*Trichobaris texana.*
Fig. 2.—*Conotrachelus erinaceus.*
Fig. 3.—*Anthonomus fulvus.*
Fig. 4.—*Disonycha triangularis.*
Fig. 5.—*Hippodamia convergens.*
Fig. 6.—*Olibrus* sp.



VARIOUS INSECTS KILLED BY THE CHINCH-BUG FUNGUS, SPOROTRICHUM GLOBULIFERUM. (ORIGINAL.)

Fig. 1.—*Macrocephalus* sp.
Fig. 2.—*Microtoma atrata*.
Fig. 3.—*Coriscus ferus*.
Fig. 4.—*Coriscus ferus*, nymph.
Figs. 5 and 6.—Unidentified larvæ.

fields not artifically treated would then show merely a spontaneous outbreak with a lower percentage of mortality. The settlement of these problems was merely a matter of experiment under conditions that would cover possibilities mentioned above. As soon as spring opened and weather permitted, field investigations began; the purpose being to ascertain whether artificial treatment of a field infested by chinch bugs would prove profitable. One phase of the matter as described earlier in this paper had already been settled; the Sporotrichum disease was widespread naturally over the infested section of the State. It remained to be shown, first, whether sowing fungus spores in an already infested field would increase the epidemic, and, second, in a field showing but little evidence of Sporotrichum whether such a treatment would start an epidemic, otherwise improbable.

Artificial Infection Experiments with Sporotrichum in the Laboratory.

Preparatory to the field work it was found necessary to experiment with the fungus in the laboratory in order to determine the best method of propagation and the effect of the artificially grown cultures on chinch bugs. Quite definite results had already been obtained by Stevens, Barber, and Forbes, and advantage was taken of their conclusions, but at the same time it was thought best to experiment anew and adopt the methods best adapted to the experiments in hand.

Sporotrichum was first isolated from transfers made into nutrient agar from a chinch bug dead of the disease. Once obtained pure, there was no difficulty in propagating it on artificial media.

For field infection large quantities were needed, so that infection boxes which were designated for infecting bugs for distribution to farmers proved inadequate. The 10 c. m. petri dish used in bacteriological investigation was selected as the vessel in which to place the nutrient medium for growing the Sporotrichum. The fungus will grow on ordinary beef broth agar, but this was not found so useful as a combination of potato extract and corn meal.

Virulence of artificial cultures.—It was realized early in the investigation that the value of any work along lines of field infection depended upon a knowledge of the virulence of artificial cultures, since these were to be employed to a large extent. It was found that so much more fungus could be produced artificially with such certainty that diseased bugs, while used, were not depended on for the major part of the work. To test the virulence of the fungus, experiments were conducted at various times by artificially infecting chinch bugs with culture fungus (that grown on the potato-cornmeal medium) and then comparing results with others not so infected or infected by the use of diseased bugs.

Experiment 1.—This experiment was started April 29, the bugs being collected at Colony, a locality which showed an extraordinarily small amount of Sporotrichum in the soil when compared with other localities (except Garnett, in the same county). By selecting bugs from Colony it was hoped to avoid, as far as possible, the presence of spores on the bugs or in the soil before the experiment began. The insects were collected in five sterile bottles, with an approximately equal quantity in each. One bottle was infected with spores from an artificially grown culture. The other four bottles were not opened after they were sealed in the field. By May 13 three diseased bugs were noted in the infected bottle. Four days later all the bugs in the bottle were dead and about half of them were covered with a visible and typical growth of Sporotrichum. The bugs were dead in the four check bottles, but no fungus developed.

Experiment 2.—This experiment was designed to reach the same as the previous one, but by a different method. It began May 7. Six screw-capped bottles, each containing 100 grams of earth, were sterilized in an autoclave. Bugs direct from the field and not artificially infected were placed in three of them. To the other three bottles were added bugs, in approximately equal numbers, which had been allowed to crawl for two hours over a moist Sporotrichum culture.

Final observations were taken 10 days later. In the uninfected bottles no fungus developed. Two of the other three contained two and eight diseased bugs, respectively. No fungus appeared on the third. The short period of 10 days duration to an extent eliminated deaths by Sporotrichum resulting from extreme weakness due to prolonged incarceration and starvation.

Experiment 3.—This experiment was designed to compare the relative effectiveness of fungus grown on a culture medium and that arising naturally on chinch bugs. Thirty screw-capped bottles were prepared with 100 grams of soil in each bottle, then the whole was sterilized in the autoclave. About 18 chinch bugs were placed in each bottle. A sterile pair of forceps was used to transfer the bugs, and unsterilized field earth was avoided as far as possible. Bottles 1 to 10 were checks, No. 10 having no infected material added. Bottle 11 contained bugs which had been shaken up in a small box with three fungus-covered bugs which were finally added to the bottle before it was sealed. Bottle 12 was prepared in the same manner. Bottles 13–17 contained bugs that had been shaken up with a lot of crushed diseased bugs. Bottles 18–20 contained bugs that had been shaken up with soil which had previously been made infectious by rubbing up diseased bugs in it. Bottles 21–30 contained bugs that had been allowed to crawl over a mass of Sporotrichum grown on culture medium.

All bugs were collected at Cherryvale, a locality that showed an abundance of Sporotrichum in the soil; hence the positive results in the check bottles. The experiment began May 7, and by May 24 all the bugs in all the bottles were dead.

The results are tabulated below:

BOTTLES 1 TO 10.

Bottle No.	1	2	3	4	5	6	7	8	9	10
Date.	Number of diseased bugs.									
May 10	....	....	....	....	....	....	....	....	....	....
May 13	1	....	....	....	....	....	....	....	....	....
May 16	1	....	....	1	....	....	....	....	....	....
May 24	1	1	2	1	1	....	1	2	....	1

Total number of diseased bugs, 13.

BOTTLES 11 TO 20.

Bottle No.	11	12	13	14	15	16	17	18	19	20
Date.	Number of diseased bugs.									
May 10	2	....	....	....	....	1	3	....	2	1
May 13	1	1	1	2	2	1	....	2	....	....
May 16	1	2	1	2	2	1	2	....	....	4
May 24	1	1	6	4	....	....	1	1	1	4

Total number of diseased bugs, 53.

BOTTLES 21 TO 30.

Bottle No.	21	22	23	24	25	26	27	28	29	30
Date.	Number of diseased bugs.									
May 10	....	....	....	....	....	....	....	....	....	....
May 13	1	2	....	....	3	1	1	1	....	....
May 16	....	....	....	....	....	2	....	....	....	1
May 24	17	6	11	1	3	10	15	6	15	9

Total number of diseased bugs, 105.

It is possible that bottles 21–30 had more spores attached to them than those in the other bottles, but that the spores possessed virulence is shown by the results in mortality.

Experiment 4.—This experiment was begun May 17. Forty-eight screw-capped bottles, each containing an equal amount of earth, were sterilized in an autoclave. Twelve adult chinch bugs were then placed in each bottle. Twenty-four bottles were kept as checks (uninoculated), and 24 were inoculated as follows: Thirteen bottles by allowing bugs to crawl over spores from a culture and 11 bottles by scattering similar spores into the bottles with a camel's-hair brush. The brush was rolled in a mass of the spores in a petri-dish culture and then struck sharply against the lip of the bottle. A cloud

of spores was thereby dislodged, which so filled the bottle that every chinch bug must have come into contact with them.

On May 22 the results were as follows:

Bottle No.	1	2	3	4	5	6	7	8	9	10	11	12	13
	Number of diseased bugs.												
Inoculated	4	8	10	12	12	11	12	10	11	11	8	9	12
Checks	0	0	1	0	1	0	0	0	1	0	2	1	1

Bottle No.	14	15	16	17	18	19	20	21	22	23	24	Total.
	Number of diseased bugs.											
Inoculated	7	12	10	6	5	9	8	10	11	10	9	227
Checks	0	1	0	0	0	0	1	0	2	1	0	12

Experiment 5.—The last of the series on virulence was begun on July 14, this late date being selected for the reason that the cultures then in the laboratory had been running saprophytically since the original isolation of the fungus in January, 1910, and there was a question whether such prolonged cultivation on artificial media had had the effect of lowering the virulence and hence weakening the power of the fungus in attacking chinch bugs.

As the latter part of July was the time in which the field experiments were terminated, it was pertinent to know whether the fungus used in field inoculation during June and July had retained the parasitic nature evidenced by the earlier experiments of this series on virulence. Experiment 5 was arranged to compare inoculations with artificially grown fungus with natural infection. Natural infection was presupposed, since there was no field found where Sporotrichum did not exist naturally to some, even though to small, extent. The method of procedure differed but slightly from that in experiment 4. Forty screw-capped bottles were partially filled with 100 grams each of moistened and thoroughly mixed earth. They were then sterilized with 15 pounds pressure in an autoclave. Ten adult chinch bugs were placed in each bottle. Twenty bottles were infected by the camel's-hair brush method described in experiment 4. The other 20 were checks.

The bottles were watched, and it was soon noticed that Sporotrichum was appearing among the treated bugs at a much faster rate than among the untreated. The disease in the checks was undoubtedly introduced with the bugs and was present on them when they were collected from the field. But the same amount of natural fungus approximately would be present in the bugs in the inoculated bottles, so that final results would be but little affected.

The bottles were opened July 23 and the number of Sporotrichum-covered bugs ascertained.

CHECK BOTTLES.

Bottle No.	1	2	3	4	5	6	7	8	9	10	11
Number of diseased bugs	0	1	0	0	0	0	0	0	1	1	1

Bottle No.	12	13	14	15	16	17	18	19	20	Total.
Number of diseased bugs	0	1	0	1	0	0	0	1	2	9

INOCULATED BOTTLES.

Bottle No.	1	2	3	4	5	6	7	8	9	10	11
Number of diseased bugs	6	5	6	7	3	3	8	4	2	1	2

Bottle No.	12	13	14	15	16	17	18	19	20	Total.
Number of diseased bugs	1	1	1	0	1	2	0	4	6	63

The five experiments pointed uniformly to one conclusion—that no mistake had been made in adopting artificially grown fungus in preference to that found on dead bugs, especially when it was found that so much more could, with certainty, be procured. In a great majority of instances in which field inoculation was undertaken the natural presence of the diseased bugs in large amounts would have rendered ineffectual the scattering of the comparatively few bugs obtained from infection boxes.

Dr. M. A. Barber, director of the clinical laboratories of the university and inventor of the technique by which single bacterial cells or spores may be manipulated at will, conducted some inoculation experiments that shed light on the problem of virulence and infectiousness of artificial cultures. He has outlined his work below:

In the following experiments spores of *Sporotrichum globuliferum* were inoculated directly into the bodies of chinch bugs by means of very fine pointed pipettes made of hard Jena glass. Very small quantities of an emulsion of spores in salt solution were drawn into the tip of the pipette by means of a suction on a rubber tube attached to the blunt end of the pipette. The point of the pipette was then inserted into the leg or abdomen of the insect and the spores forced in by gently blowing into the rubber tube. Inoculation was done under a large simple lens. The same technique has been successfully used in the inoculation of flies, cockroaches, and other insects with bacteria and various microorganisms.

The experiments with chinch bugs were undertaken largely for the purpose of testing the technique, and the number of series undertaken

was too small to warrant any definite conclusions. The results, however, indicate that chinch bugs may survive the injury made by the pipette, that direct inoculation into the body is more surely followed by infection than exposure to spores placed only on the surface of the body, and that introduction of spores into the abdomen gives a larger proportion of infections than inoculation into the leg.

One series is given below as an example of the method employed. It differs, of course, from the natural one, but the technique is of service in testing the conditions of infection, as the virulence of spores grown artificially on culture media or the resistance of insects kept under different conditions or in different stages of growth.

All chinch bugs used in the experiments were taken from the same lot, and all were inoculated with an emulsion in physiological salt solution of spores of *Sporotrichum globuliferum* taken from a 21-day agar culture.

Twelve or more insects are included in each group. This culture was one derived from a series of transfers beginning with an original transfer made from a diseased chinch bug in January, 1910.

Group.	Inoculated May 26.	May 31.	June 2.	June 6.
1	In legs; at least contact of spores with injured surface.	No apparent fungus growth; some bugs still living.	Beginning of growth, apparently Sporotrichum; growth first appearing on leg; all bugs dead.	Majority of bugs covered with Sporotrichum.
2	Spores placed on uninjured leg.	No fungus growth apparent; some bugs still living.	No fungus growth apparent; some bugs still living.	Several bugs with Sporotrichum; some still living.
3	Inoculated in abdomen.	Beginning of fungus growth; all bugs dead.	All or nearly all covered with Sporotrichum.	Apparently all covered with Sporotrichum.
4	Controls; no spores added.	Apparently no infection; some bugs living.	Apparently no infection; some bugs living.	Apparently no infection; at least one bug living.

Artificial Infection—Field Experiments.

The fungus material used in the following experiments was grown in the laboratory by methods already described. In the field the dried petri-dish cultures were rubbed up with dry earth, making a mixture that was light-colored, due to the large admixture of spores. The mixture was dusted directly on the bugs on the infested wheat or corn, and on the ground at the base of wheat, where the insects congregated.

Shading experiments.—To test the effect of shade, artificially produced, on Sporotrichum in its parasitic relation to chinch bugs, small

plots of shade-giving, low-statured plants were set out in certain badly infested wheat fields. Shading experiments of a different nature were tried in cornfields, but these will be discussed in another place.

The plots were set out to beans or cowpeas, as the case might be (the former proving the better), and were 50 feet square. A row of beans a foot wide formed the four sides of the square, and four rows, each a foot wide, were planted across the square, 10 feet apart, so that they would intersect the wheat rows at right angles. The appearance of each plot when finished was that of a gridiron.

The original purpose was to provide such shade that chinch bugs traveling along the wheat rows would encounter the shade and the moisture conditions of the bean rows. The beans were planted thickly, so that when the plants grew to 8 or 10 inches in height the ground beneath them was moist when that elsewhere would be dry. It was hoped that the wheat would come into close connection with the bean rows, but this was not always the case. It was hoped, also, that the bugs would seek the shade, and thereby enter conditions which would favor the development of Sporotrichum. It was found, however, that the bugs did not collect under the beans to any extent, nor did they appear to pass across the rows except in a few instances. Hence the infection sown among the beans, or cowpeas, failed to gain a favorable opportunity to come into contact with the bugs. While as a shading experiment the bean plots were of no value, they served a most excellent use as areas of infection or centers of infection. As they were laid out directly in the wheat they contained chinch bugs in as great numbers as the wheat outside them. Fungus was sown in them in large amounts, so that one might expect one of two results: (1) The chinch bugs inclosed by the plots showing greater mortality by Sporotrichum; (2) the plots becoming centers of field infection, with the greatest effect seen nearest the plots themselves. In most instances the experimental areas exhibited spontaneous outbreaks of Sporotrichum, and, with the fungus sown artificially, the plots contained an extensive amount of infectious material. In each experimental field, where a 50 by 50 foot experimental area was inoculated with fungus spores, a check area, or plot, similar in every way, was laid out from 100 to 200 yards distant. By comparing the two plots the effect of the artificial infection could be judged better.

The spread of the disease, if any occurred, was watched not only in the experimental areas but in other parts of the field and in fields at distances from a fourth of a mile to several miles.

Artificial infection—Localities in which field experiments were conducted.—In the selection of fields for artificial infection the first prerequisite was the presence of large numbers of chinch bugs, since a contagion of any kind spreads faster, other things being equal,

where congestion is greatest. A second desideratum was the scattering of the centers of field work in such a manner that results would be general for the entire infested area of Kansas rather than local in character. Varied conditions would then be encountered; for example, one section would have less rainfall; another lighter soil; one with Sporotrichum abundant in the soil, another with it scarce. As to extremes of latitude, one county in the northern portion of the State and three along the southern border were chosen. With these things in mind, the following sections of the State, with the towns near which activities were carried on, were selected:

South-central section: Wellington, Sumner County.

Middle-central section: Newton, Harvey County.

North-central section: Lebanon, Smith County.

Southeastern section: Cherryvale and Independence, Montgomery County; Fredonia, Wilson County; Parsons, Labette County; Thayer, Neosho County.

Middle-eastern section: Colony and Garnett, Anderson County; Lebo, Coffey County.

Field notes covering observations made at intervals were, of course, carefully taken. Records of precipitation were furnished by a local or near-by observer in the Weather Bureau service. In a few instances rain gauges were provided and records kept for the immediate vicinity of the experimental farms.

The method of procedure in each locality was essentially the same. Until wheat harvest, artificial infection was confined principally to the wheat fields, though in a few instances oats and young corn, when badly infested, were also treated. Fields in which chinch bugs were particularly numerous were deemed best suited for artificial infection. Several such fields were generally selected, the owners' consent obtained, and either 50-foot plots laid out or inoculation made of some definite corner, side, or marked spot.

The experimental fields were examined before any infection was set out, to ascertain, if possible, the presence of the fungus naturally in the soil. Direct observation of fungus-covered bugs was one kind of evidence used. If these were lacking, as was the case earlier in the spring, when dry conditions prevailed over the entire State, sterile bottles filled with bugs and earth were used, with the expectation that the fungus would break out spontaneously on the bugs when in moist conditions under confinement. In almost every instance the experimental field was thus shown to contain Sporotrichum before any spores were sown artificially. The only reason for continuing with the artificial inoculation experiments was to determine whether the extra amount of infectious material added would induce an epidemic, when under normal conditions only a slight outbreak would occur.

Check fields, uninoculated and at distances varying from a quarter of a mile to several miles, were carefully observed, as they constituted the key to the situation.

It will not be necessary to give the field notes for all the localities in full, since a few will suffice to show how the work was conducted.

Sumner County.—Attention was first called to the vicinity of Wellington, in which chinch bugs promised to be extremely troublesome. Collections of the bugs early in the spring confirmed the report. Sporotrichum was known to be present in the soil because of its presence in the bottle culture used as tests.

The use of three wheat fields was kindly permitted by Messrs. Lynch, Banks, and Russell. Other farmers offered the use of their fields, but the three mentioned were found to be the most favorable in point of wheat prospects and numbers of bugs. The experiments on two of them will be described in detail.

Experiments in Mr. Lynch's field.—Two plots, 50 feet square and planted gridiron fashion, with a dwarf variety of beans, were set out about 150 yards apart in the wheat field northwest of the Lynch residence. The plots contained approximately the same number of bugs, but the wheat was ranker in one than in the other. It grew finally so tall and close that its shade greatly exceeded that given by the beans. The beans were sown in the latter part of April, but it was not until about May 18 that the plants were high enough to make sufficient shade. On May 18 the field was examined for chinch bugs dead of Sporotrichum that existed naturally in the soil. They were found in both plots; also in other parts of the field. The part selected for artificial infection was near the center of the field, by an old strawstack. The check plot was that containing the ranker growth of wheat. Owing to the shade in the check, the conditions for fungus development were deemed better, but, on the other hand, the plot with the thinner growth contained more spores, owing to the artificial infection. About 20 dried petri-dish cultures were stirred into a bucket of dry soil, and the mixture, whitened with the spores, was sown along the wheat rows and under the beans. There was no doubt but that the swarms of bugs around the wheat came into close contact with the infection. In addition, they jostled almost continuously the whitened corpses of bugs, already dead of the Sporotrichum disease.

A shading experiment, in which straw was used, was conducted near the infected spot. Small piles of straw were laid both between the wheat rows and around the wheat. Fungus-infected earth was then liberally sown in the straw and under it. The straw was utilized to keep the ground beneath moist, so that if bugs frequented the straw to any extent they would find conditions more favorable than out in the open. Many would contract the disease, perhaps, and then leaving the piles die in other locations, thus scattering the infection.

On May 25 a second and thorough infection of the previously infected plot and straw piles was made. At the same time results

of the previous inoculations were looked for and the general situation examined. Diseased bugs were found in both plots, more being found in the check. Recent rains that had moistened the soil now showed no effect on the surface, except where the wheat was rank. Bugs were dead in all parts of the field, and in many places the dead bugs were as numerous as in the infected plot. Under the straw that had been packed around the wheat there were more diseased bugs found than anywhere else; but there were no more, apparently, near the piles than at a distance from them, so that the infection had not spread, to any appreciable degree, at least.

Chinch bugs, young and old, swarmed along the wheat rows, with no more dead ones in the infected plot than outside of it, or in many other parts of the field. Clearly the artificial infection had yielded no results. The wheat was showing the effects of dry weather as well as the attacks of the bugs. It was found that the beans gave entirely negative results. While the ground remained moist longer beneath them, the chinch bugs did not frequent them to any extent.

On June 12 the Lynch field was again visited. The greatest number of living, as well as of diseased bugs, was found in the check plot, with its rank wheat. Conditions elsewhere were about as they were on the previous visit. The wheat had turned yellow and was nearly ready for harvesting. In the 25 days since the first infection in which the artificially sown fungus had been allowed to act, the moist conditions resulting from two periods of precipitation had favored the growth of Sporotrichum. On the whole, however, the period had been dry. The drought had not prevented a general spontaneous outbreak, but it probably checked its severity. The artificially infected plot had not only the bugs dead of the Sporotrichum naturally present, but it had relatively enormous quantities of culture fungus, so that as to intensity of infection it was much more thoroughly treated than would have ever been possible with diseased bugs, or than it would have been had the spores been spread over an entire field. The artificial inoculation was a failure in that it did not perceptibly decrease the number of bugs in the 50-foot plot, when compared with the area about it and with the check; nor did the fungus spread from the treated plot or the straw piles. The check had more diseased bugs than the treated plot, but this may have been due to the moister conditions produced by shade or to greater numbers in the first place. Apparently the presence or absence of the culture fungus did not affect the problem.

As check fields to the Lynch fields, three were examined, the nearest being about a fourth of a mile distant, the other two one-half and three-fourths of a mile distant, respectively. None had been artificially infected, yet each contained diseased bugs.

Experiments on Mr. Banks's place.—The field offered for experimental use was on a slope south of the house. Like the Lynch field, one had contained a rank growth and the other a thin stand of wheat; but the rank growth was denser and the thin growth was poorer than that found on Mr. Lynch's place. In order to balance matters the bean plot set out in the dense growth of wheat was used for artificial infection, while that in the thin growth served as a check. It was noticed that diseased chinch bugs were present in all parts of the field before any fungus had been distributed. The first inoculation was made May 18. Cultures were mixed with the earth and sown as in the Lynch field. The beans were useless, as they were shaded by the wheat. The ground was moist in both plots, and especially in the treated one. Observations were taken May 25. Both plots, as well as the remainder of the field, contained diseased bugs, but the dense growth showed the greatest number, outside the plot as well as inside. Had not the Lynch field served as a kind of control these results might have been regarded in part as favorable to artificial infection. On the same date (May 25) a second distribution of fungus was made in this plot. Final observations were taken June 12, but there was no change in the results. The favorable conditions of shade and moisture favored Sporotrichum. No matter whether fungus spores were added or not, about the same number of bugs died, and there were more than in a plot where the sun had a better access to the soil and where conditions were drier. The fungus showed no tendency to spread. The bugs had begun to migrate into the neighboring oats and the cornfields. A wheat field about a fourth of a mile distant, untreated, contained many diseased bugs. Other check fields were the Cann place and the Ruggles place, both about 3 miles distant. Diseased bugs were plentiful in all of them.

Weather conditions.—Statistics as to humidity and precipitation for the district around Wellington were kindly gathered by Mr. E. O. G. Kelly and his associate, the former an assistant in the Bureau of Entomology of the United States Department of Agriculture. The recording instruments were kept at the station, which was approximately the center of the area that would include the three experimental fields. Observations covered most of May and June, during which field investigations were going on. Total precipitation recorded by Mr. Kelly, 6.13 inches. The total for April, May, and June at Rome, a few miles south, was 6.27 inches.

The spring and early summer were unusually dry, as the average monthly rainfall for the district around Rome was lower than the normal by the following amounts: April, 1.59 inches; May, 1.23 inches; and June, 3.32 inches. In spite of the diminished precipitation, however, spontaneous outbreaks of Sporotrichum occurred all about Wellington, no field containing chinch bugs failing to exhibit the whitened, fungus-covered bugs.

North-central section, Smith County, Lebanon.—For this section Lebanon was selected as a favorable place for carrying on some field experiments. Accordingly, one of the writers went to Lebanon, April 18, and with the assistance of Dr. W. C. Bower and Mr. Charles Isom selected five fields in which to experiment. The details of the work in one field only, that of Charles Sargent, will be given, as the results in all these experiments were the same.

At the time of our visit it was very dry. On the 20th a severe dust storm prevented us from going to the country. The bugs were plentiful in all the fields visited, but no diseased bugs were found.

Experiments in Mr. Sargent's field.—On April 21 Mr. Sargent's field was examined for diseased bugs, but none was found, though living ones were abundant. On May 10 a supply of Sporotrichum was sent to Mr. Sargent with which to infect his field. On May 12 it was mixed with earth and distributed along a small draw where bugs were thick, wheat was rank, and moisture conditions were favorable. Small bunches of straw were also infected. The field was examined May 31 for results. Occasional dead bugs could be found in all parts of the field, but, on the whole, diseased insects were scarce. There were more of them, however, in the draw where the infection was placed than elsewhere, but this might have been caused quite as much by the more favorable conditions there as by artificial infection. There seemed to be a few more diseased bugs also in the immediate vicinity of the bunches of straw than at a distance of a few yards away, but the difference was so slight that the experiment could scarcely be called successful. On the same date Mr. Moore's field, 1 mile south, and Mr. Waddles's field, 1 mile north, were inspected, and diseased bugs were found in both of them, though they had not been infected artificially. There was no appreciable difference in respect to the number of dead bugs in the fields.

On this date (May 31) a second distribution of fungus was made in the draw. Spores were dusted directly from the cultures upon the bases of the wheat, where the bugs were most plentiful. This was done in two definite areas, which were carefully marked.

During wheat harvest, June 28, the field was again visited. Diseased bugs were much more numerous all over the field than at the time of the previous visit. Especially was this true along the draw where in some spots the diseased bugs were thick enough to whiten the ground. In and around the two infected spots, however, there were no more diseased bugs than in equally favorable spots elsewhere. Young bugs were still swarming in the wheat in vast multitudes, so that the fungus did not materially help the field, though a good many died, especially among the old bugs. Two factors may have been at work in the outbreak of Sporotrichum; one, the artificial infection, the other, the favorable conditions acting in conjunction with the

fungus naturally present in the soil. In analyzing the factors, the distribution of the dead bugs was taken to be the important element. A search of the field showed that they were thicker in some parts than in others, but numbers were related to conditions of moisture rather than to centers of artificial infection. Hence it is not improbable that the situation would not have been appreciably altered had no fungus been sown in the field. Other fields near Lebanon in which no Sporotrichum had been introduced, or at least not until a later date, were used as checks, and particularly the Moore field, 1 mile south, and the Waddles field, 1 mile north. They were examined carefully on the same dates as the Sargent field, and at no time was there any perceptible difference, so far as diseased bugs were concerned, in the three fields. All the check fields contained diseased bugs in considerable numbers, especially where the conditions were particularly favorable. Owing to artificial infection of the Sargent field before the time was ripe for a general spontaneous outbreak of Sporotrichum, the occurrence of the outbreak in this field had all the appearance of being due to the sowing of the fungus. To a casual observer the success of artificial infection would have been regarded as indisputable, though of course partial, since not all the chinch bugs were killed. It is likely that some of the "successes" reported by farmers in former years were due to a misinterpretation of such appearances of Sporotrichum among the bugs.

The results of the experiments at Lebanon showed the importance of moisture conditions as factors in the development of the Sporotrichum disease, especially in a dry season, and at the same time how unimportant a factor is the sowing of the fungus spores.

Total precipitation at Lebanon for the months of April, May, and June, 1910, 6.85 inches, which was 2.08 inches less than the average. For May, however, the rainfall was 0.04 inch greater than the average. The greatest deficiency in precipitation was during April.

Southeastern section, Montgomery County, Cherryvale.—Three farmers near Cherryvale kindly offered the use of their wheat fields for experimentation. They were Mr. Metcalf, Mr. Benham, and Mr. Darling. The vicinity of Cherryvale was badly infested with bugs and hence offered a favorable opportunity for experiment. The eastern portion of the State, moreover, exhibited better climatic conditions, owing to greater rainfall and humidity.

On April 27 collection of bugs and earth in sterile jars was made from each of the three fields mentioned above. Sporotrichum developed readily, thus showing the presence of the fungus naturally in the soil. On the Benham and Darling places, 50-foot plots of the usual type were set out to cowpeas and placed about 100 yards apart.

The cowpeas did not prove of any advantage as to shade, and so the plots were used to mark the areas for infection and check.

Experiments in Mr. Metcalf's field.—This field was located about 4 miles north of town and was the worst infested place seen around Cherryvale. No plots were set out, but the infection of it was left in the hands of Mr. Metcalf himself, who scattered the fungus generally over the field. On May 2 a large package of fungus culture was shipped, with instructions as to mixing with soil and distributing through his field. On May 13 a second lot was sent, and a third shipment was made May 22.

On May 26 a visit was made to the field. Up to this time there had been two artificial distributions of the fungus culture, and also several of diseased chinch bugs taken from an infection box. Living bugs were exceedingly numerous, and the conditions for their destruction by Sporotrichum were to all appearances ideal, as rainfall, a moisture-retaining soil, and high humidity for much of the time conspired to render the spread of the fungus easy. An outbreak of Sporotrichum occurred early in May, and by May 26 had succeeded in killing many thousands of chinch bugs, so that they were plainly in evidence on the ground all over the field, yet so numerous were the living ones that the dead ones were at any time only a small percentage. Had not the check fields been watched, the outbreak might have been attributed directly to an artificial infection. In fact, it seemed to Mr. Metcalf, at least at first, that the fungus he had sown was quite successful, especially as he had put it out before any appearance of diseased bugs was manifest. But spontaneous outbreaks occurred in all the fields examined around Cherryvale at about the same time, and no difference was noticed as to whether a field had been artificially infected or not. One can readily see how a farmer, observing the state of affairs merely on his own place, would be convinced of the success of his artificial infection and would send in his report accordingly.

So plausible was the evidence to Mr. Metcalf that it was only with difficulty that he was convinced after visiting a check field owned by Mr. Steinburger and located 1½ miles distant. The Steinburger field was nearly as badly infested as was Mr. Metcalf's, and the diseased bugs appeared more numerous than on his own, though no artificial infection had been used.

On this date (May 26) the Metcalf field was artificially infected by fungus culture for the third time. The amount of fungus added to the field was, of course, a small proportion of that found naturally on the thousands of dead bugs scattered through it. On June 23, about harvest time, the field was again visited. Conditions were found to be about the same as on the previous visit. Two check fields other than Mr. Steinburger's, lying about 2 miles distant, were used for comparison. Both had numerous living bugs and as extensive spontaneous outbreaks of Sporotrichum as any field around Cherryvale.

Montgomery County, Independence.—The experiments conducted at Independence were under the supervision of Leslie A. Kenoyer, a graduate in science of the University of Kansas. Mr. Kenoyer lived at home, on the farm, while carrying on his work, and was therefore able by constant residence to watch the progress of events in a most satisfactory manner. His observations, however, were checked up from time to time. His final report is given below in full.

MR. L. A. KENOYER'S REPORT OF HIS EXPERIMENTS WITH SPOROTRICHUM AND THE CHINCH BUG.

My observations on chinch bugs near Independence, Montgomery County, Kans., covered a period of nearly three months—from March 20 until June 14, 1910.

The bugs were found to occur in most grain fields. They were, as a rule, most abundant near the borders of the field, and especially adjoining hedges of Osage orange. These hedges are numerous in this county and they appear to be excellent harboring places for the bugs, chiefly, it appears, by reason of the weeds and grass which collect there. Even spring burning does not seem to destroy the bugs.

Dr. F. H. Billings and I planted bush beans around several selected plots of grain about April 15. The plots chosen were 50 feet square. A trench 1 foot wide was made around each and four similar trenches were placed across the square at intervals of 10 feet—the whole having the form of a gridiron. The beans were thickly sown in the trenches. In the Evans and the Page wheat fields two plots in each were thus arranged, the one to be infected and the other to serve as a check. In the Kellenberger oat field one plot was planted and kept infected. In the Evans wheat field two plots of the same size and appearance as those planted to beans were laid out by means of strips of old straw 1 foot broad. One was infected and the other left as a check. In a neighboring field small piles of straw and of fresh weeds were placed at intervals and kept infected.

The end sought in these experiments was a method of supplying shade and moisture enough to encourage the development of the fungus.

Fungus grown at the University of Kansas on a preparation of corn meal and potato extract was pulverized, mixed with dry dust or sand, and scattered in the bean rows and strips of straw.

In the Page field the plots were planted just south of a hedge, along which were a good many bugs in the spring. The plots were about 60 rods apart. The west one was infected May 7 and May 14. As the bugs seemed to diminish in numbers along the hedge, no more fungus was placed in this field. At the last examination, June 11, a few living and a few fungus-covered bugs were found in both

places. Both living and dead seemed to be rather more numerous in the noninfected plot, but the results were indecisive.

Fungus was sprinkled on the bean plot in the Kellenberger oats field May 7, May 14, May 26, and June 4. Bugs did not become plentiful in this field and very few young ones appeared. There were a few more, both living and diseased, in and about the infected plot than elsewhere. But wherever there were living bugs, diseased ones could be found by a little searching.

In the Evans field the bean plots were located just north of a hedge and about 40 rods apart. The east plot was infected on the above-mentioned dates. Bugs continued very numerous all spring in this field. Hordes of young ones appeared about the middle of May and their influence, added to that of an early spring drought, killed much of the wheat before it was ripe. Fungus developed all over the field so freely that by the middle of June from 50 to 100 dead and whitened bugs could frequently be found around the bases and on the roots of a single hill. While the fungus appeared in all parts of the field it was in general more abundant at the west end, so it chanced that the uninfected bean plot showed decidedly more fungus than the infected one.

The " east " straw plot was infected on the same dates as the bean plot and the " west " plot was left as a check. On neither one were the bugs as numerous as along the side of the field on which the beans were planted, but both living and dead bugs were to be seen in about equal numbers in the infected plot and the check plot.

The piles of straw and those of weeds were likewise infected, but without any appreciable increase in the death rate of the bugs.

Although the beans had made a very good shade before harvest time, the bugs showed no marked tendency to seek the shade. They are more active on sunny days than in cool, cloudy weather, and when crawling from hill to hill they appear to seek sunshine rather than shade.

After the wheat had ripened the bugs crawled up the bean bushes in considerable numbers, and many dead fungus-covered bugs could be seen adhering to the leaves of the plants and to the young beans. Famine had evidently aided the plague in this case. But here again there was no difference in favor of infected portions.

To determine the efficiency of the distribution of dead bugs in fields I selected an oats field on the Evans farm, one-fourth of a mile from the experimental wheat field. A strip of about 3 by 10 yards was sprinkled on May 25, May 28, and June 4 with diseased bugs grown in culture boxes. Developments on this portion were in no way different from those on the remainder of the field.

On April 20 a pint fruit jar was scalded and half filled with bugs and soil from the Evans wheat field. Sporotrichum developed in

from 8 to 10 days, showing quite conclusively that the spores were present in the soil.

In a field of wheat and in one of rye, west of the infected fields and about three-fourths of a mile distant from any of them, diseased bugs were found in the early part of June in as great numbers as in the Evans field just mentioned. The chance of material from my infections having reached these fields was very improbable. Several other fields were examined and none was free from infected bugs where bugs were plentiful in the period preceding harvest. But the proportion of diseased bugs varied considerably from field to field. And apparently in no case had the fungus produced an epidemic sufficient to materially reduce the number of bugs or to save the crop.

My experience with infection boxes was not such as to greatly encourage the infection idea. Living bugs were confined with diseased ones in boxes of moist earth for weeks at a time, and only a very few became infected. Later in the season, when the disease became common in the fields, it spread more readily in my boxes.

My observations lead to the following conclusions:

1. Sporotrichum occurred naturally in the soil of all of the fields.
2. The distribution of the spores or of spore-covered bugs in a field had no noticeable effect upon the dying of bugs.
3. Bugs died spontaneously when the weather was sufficiently moist and when the ripening of the grain diminished their food supply.
4. Spontaneous infection did not spread to such an extent as to materially benefit the crop.

The results attained in the preceding report were confirmed by observations made during the experiments. The results fully accord with those obtained elsewhere, and are of particular value because of the favorable moisture conditions and the larger number of chinch bugs. In the Evans field the young bugs suffered more severely by attacks of the fungus than in any other field investigated.

Weather conditions for Cherryvale and Independence.—The weather statistics for these two centers of experimental work were gathered by Mr. F. L. Kenoyer, of Independence, and we hereby express our thanks to him for his kindness in taking humidity readings and furnishing a copy of the precipitation record. During the month of May and the fore part of June, southeastern Kansas had a rainfall in excess of the average and a relatively high humidity. The soil in this section, being mostly heavy, retained the moisture well. The conditions for fungus propagation seemed to be ideal during a part, at least, of the period of growth of the new brood of chinch bugs. While adults seemed to succumb first, many young were affected, especially at Independence.

The total precipitation at Independence for the months of April, May, and June, 1910, was 10.97 inches, which was 4.70 inches in excess of that of Rome (near Wellington, in Sumner County). The rainfall for May alone at Independence was 6.25 inches, or about the same as for the three months near Wellington. The May precipitation was 6.25 inches, or 1.44 inches in excess of the average. In addition to the unusual total precipitation for this month, the rainfall was well distributed. There were 19 cloudy days in May, and 5 partly cloudy, so that the month was damp for most of the time. Conditions were very favorable for Sporotrichum from the first week in May until the harvest time, and it was certain that the fungus responded by attacking vigorously both young and old bugs. Notwithstanding the favorable conditions, there were plenty of bugs left at harvest time—enough to do great injury to the corn.

Anderson County, Colony and Garnett.—The experiments of Colony only will be outlined below. Two fields were used for experiment, but the field notes taken on Mr. Quiett's place will suffice for the purpose.

Experiments on Mr. W. A. Quiett's place.—Work began on Mr. Quiett's place on April 20, when a field of wheat was searched for diseased bugs. While none was found, living bugs were numerous, and two bottles of bugs and earth were collected to see if Sporotrichum would develop spontaneously. The results were negative. Diseased bugs were left with Mr. Quiett, so that he might start an infection box. On May 3 a supply of fungus culture was sent for field infection. It was distributed along the north side of the field. On May 19 the field was examined for results. Two diseased insects were found on the north side near the infected locality, but none was seen on the south side. It was evident, as in the Boone field, that no spontaneous outbreak had occurred. Some of the fungus had been placed under piles of straw, but there were no results in dead bugs. There had been more or less rain for about three weeks and the soil was wet. Another visit was made May 26, with no change in the condition of the field. Weather was cool and damp. Some fungus was placed at the base of the wheat in a small patch that was carefully marked. A similar patch some distance away was infected with diseased bugs and also marked. Some living bugs from the field were caught, shaken in a box with Sporotrichum spores, and then turned loose under a bunch of straw. The experiments on this date (May 26) were concluded by leaving a quantity of the fungus culture with Mr. Quiett for further field infection. The next inspection took place June 21. All parts of the field were searched for diseased bugs. Extremely few were found, and no more around the infected spots than elsewhere. The ground was damp and shaded in some places, but there were no more in evidence in

one place than in another, so far as could be seen. Harvest had begun before another visit was made, on July 12. The bugs had gone into some adjacent corn. Pupæ were very thick on the ground about the base of the stalks, under bunches of crab grass and other vegetation that afforded protection. Adults were emerging in large numbers. A few diseased bugs were found in the corn where the bugs were collected for molting. A pile of cut corn was made in the field and fungus scattered in it. A second pile was made and left uninfected. On July 30 an inspection showed that diseased bugs were still scarce, only one being found. The infected and check piles of cut corn and the locality immediately adjacent showed no effects of the infection or shading. Both piles of corn contained thousands of molted skins of the bugs, which might have been taken by an unskilled observer for dead bugs.

Results of experiments in Anderson County.—Conditions at Garnett and Colony were unique when compared with all the other places where experiments were made. Spontaneous outbreaks of Sporotrichum had been the rule, but at Garnett and Colony they were absent, or nearly so. To explain the situation, one would naturally examine the climatic conditions, since they probably have more to do with the propagation of Sporotrichum than any other factor. The following table gives some comparative data:

Place.	May and June.	
	Precipitation.	Mean temperature.
	Inches.	° *F.*
Garnett	11.31	65.5
Oswego (Parsons)	9.61	68.0
Lebo	12.46	65.6
Rome (Wellington)	4.67	68.8
Lebanon	6.19	65.1
Chanute (Thayer)	13.69	65.5
Independence	9.21	68.1
Hutchinson	....	67.1

Garnett had an abundance of moisture, but the spontaneous outbreak was only slight. Conspicuous outbreaks occurred at Lebo and Thayer, where the precipitation was greater, at Parsons and Independence, where it was but a little less, and at Wellington and Lebanon, where the precipitation was much less. The mean temperature for the two months was below normal, but not below the mean temperature of other places where spontaneous outbreaks occurred, for example, Lebanon and Thayer. It would seem, therefore, that the explanation of the fact that spontaneous outbreaks in Anderson County were so meager can not be found in the climatic condition, and must be attributed to some other factor. Was it due to a scarcity of fungus naturally present in the soil? This would seem to furnish

a plausible explanation at least, since our tests in nearly every case yielded negative results. But when large quantities of the fungus were introduced the results remained unchanged; no epidemic could be started. It seems evident, therefore, that the failure of an outbreak to occur was not always due to the lack of the fungus, but to some other factor as yet unknown.

If these two places in Anderson County are representative of those in which spontaneous outbreaks do not seem to occur, then it is evident that artificial infection does not produce such outbreaks or any beneficial effects that are commensurate with the amount of fungus introduced and the time and expense necessary in introducing it.

Corn-infection experiments at Cherryvale.—The field work at Cherryvale was more extended than at Independence and the climatic conditions were more favorable, especially during the first part of the work. The fields selected were owned by Mr. Metcalf and Mr. Botkins. They were separated by a wheat field, from which chinch bugs migrated. By the 21st of June about the first 20 rows of corn were badly infested. Two plots of corn were selected in the Metcalf field, at opposite ends of the corn rows nearest the wheat. The plots were surrounded by ridge barriers on which crude oil was placed. Each area had about as many bugs in it as the other. Both were very badly infested, and the corn gave promise of being quickly killed unless the bugs were exterminated. One of the plots was artificially infected with fungus culture. The spores were mixed with earth and dusted on the bugs. Some of the dried cultures were used without an admixture of earth. The insects swarmed on the corn in such compact bunches that large numbers could be easily dosed with fungus spores. Practically all of the bugs in the plot had an application of Sporotrichum. The other plot was used as a check. Each plot was about 40 feet long and included three rows of corn. The experiment continued for a week, or until the corn was completely killed out. The bugs were unhurt and finally escaped over the barrier and scattered into the new corn.

A new type of experiment was then tried, the chief merit being the maintenance of extremely humid conditions. The other factors, large numbers of bugs and intensity of infection, were still at hand. The experiment consisted of cutting corn badly infested with bugs and piling it in heaps, bugs and all. In the Metcalf field about a dozen stalks composed each. The top soil under each pile was removed to expose the damper subsoil, which thus assisted in preserving the dampness. The bugs repaired to the lower portions of the piles as soon as they were made, and there, with the moisture from the leaves, from the ground, or from the rain, or artificial watering, the humidity was high enough to insure propagating of the fungus.

In the Metcalf field six piles of corn were laid. Two were well watered and two of the remaining four were covered over with rank weeds to increase the shade. The last two were not watered nor covered with weeds. All were thoroughly infected throughout with Sporotrichum. Chinch bugs swarmed inside the piles and as long as the corn remained reasonably fresh they apparently made no effort to leave.

A similar series of piles was constructed in the Botkins field, only they were larger, having 40 stalks to the pile. A dozen such heaps were made, and they were about 60 feet apart. None of the piles in the Botkins field was artificially infected.

Four questions were to be decided by the corn-pile experiment: (1) Would the chinch bugs become diseased in an uninfected pile? (2) Would they become so in an artificially infected one? (3) Would the infected bugs leave the piles and carry the contagion to other parts of the field and ultimately bring on an epidemic? (4) Would the bugs die by sucking the juice of the corn, soured after cutting, as had been stated by certain farmers?

The piles were prepared June 22. Heavy rains occurred June 25 and 27, making the ground very muddy. Diseased bugs were noticed around the base of the corn in various parts of the field. The piles of cut corn were examined and a few dead bugs were found. The corn was very wet, and the lowest stalks and leaves in some of the piles were in mud. As the greater part of the leaves were still fresh, the bugs had not left the piles, but seemed quite as numerous as ever. If the juice had soured it had thus far caused no perceptible mortality among them. Molting had occurred to a considerable extent, and the old skins resembled dead bugs sufficiently to have probably caused some of the farmers to mistake them for bugs killed by sour juice or by Sporotrichum. The piles in the Botkins field, although untreated, contained more diseased bugs than the artificially infected ones in the Metcalf field. Conditions were probably more favorable in the former than in the latter case, since the corn was piled on higher ground and did not get so soggy.

Thus far no effect worth mentioning from Sporotrichum was observed in any of the piles. The diseased bugs in the piles on the Botkins place served as infection for the other bugs. It seemed as though conditions in this field could not have been made better for the spread of infection, yet the number of diseased bugs was only a very small fraction of the living.

On this date (June 27) a pile of freshly cut corn infested with bugs was made in each field, the one on the Metcalf place being infected artificially with Sporotrichum. All of the piles were examined on July 6. The original ones (made June 23) were found

to be deserted by the bugs, and the corn dry and in some instances moldy. Skins of molted bugs were very numerous, and Sporotrichum-covered carcasses were in considerable abundance, but aside from the latter there was no evidence of dead bugs, i. e., that might have been killed by sour juice, for instance. Evidently the great majority had migrated, leaving comparatively few dead behind as the result of infection by fungus.

The corn piles made on June 27 were in good condition, the corn being green and fresh. Chinch bugs still swarmed through them in multitudes, and there were old skins and quite a number of diseased bugs. There were a few more diseased bugs in the Metcalf corn pile than in that in the Botkins field, and the difference may have been chargeable to the artificial infection. The percentage of diseased insects when compared with living, however, still remained very small, so that as an effective means of propagation of Sporotrichum disease, the corn piles were a comparative failure. Quite the reverse might have been expected, since the chinch bugs remained exposed for over a week to infection under shade and moist conditions. With negative results under such circumstances artificial infection could hardly be expected to work in the open field. Almost every chinch bug in the corn piles must have come into contact with the fungus spores sooner or later, especially where artificial infection was used. After leaving the piles the bugs transported the spores to various parts of the field, but there was no evidence that the spores took effect.

By July 6 nearly all of the corn in the full 50 rows was destroyed. Infection of chinch bugs on corn by the use of fungus culture was made on this date and again on July 17. Cultures mixed with earth or used directly were employed in dusting spores on the insects. Final observations were made on July 28, five weeks after the first lot of the fungus was sown in the corn. From a practical standpoint everything was negative. At no time did the Sporotrichum disease appear to be working except in the smallest way. Perhaps the weather conditions were not just right, but at Cherryvale they were apparently right for at least part of the time and that long enough to have started an epidemic.

If the relation between climatic conditions and successful fungus propagation, however, is so exact that not once did anything like a really destructive epidemic occur during all the series of experiments and observations from April till nearly the first of August, then farmers should not for a moment think of depending on artificial infection or on the fungus disease at all for the saving of their crops. Whatever good had come from Sporotrichum as a destroyer of chinch bugs came of itself without the aid of artificial sowing of spores.

Remedial Measures and Conclusions.

The University of Kansas, during 1910, sent out 1,363 packages of diseased chinch bugs at the request of farmers, with which to start infection boxes and artificially infect their fields. The plan followed was in accordance with recommendations of Dr. Snow, who in the nineties attempted to check the ravages of chinch bugs by the distribution of *Sporotrichum globuliferum*, the cause of the well-known white-fungus disease. A series of investigations, however, was inaugurated early in the year 1910, and continued until nearly the first of August, the purpose being to ascertain the practicability of artificial infection.

The plan of work embraced the solution of the following problems: (1) Determination of the extent of the presence of the chinch-bug fungus naturally in Kansas soil, (2) practicability of artificial infection of fields after the fungus was already shown to be present, (3) practicability of artificial infection of fields containing apparently little or no Sporotrichum, and incidentally (4) ascertaining so far as possible the best method of fighting chinch bugs in case it were proved that artificial infection with fungus is not effective.

The work of solving the first problem fell naturally into two divisions, namely, (1) examination of chinch bugs for the fungus disease, while they were still in winter quarters, and (2) examination of chinch bugs for disease after migration to wheat or corn fields.

While gathering data for determining to what extent Sporotrichum was naturally present in Kansas soil, many localities in the infested area were visited. The work began in January, 1910, and extended well into the summer. As a result, 59 counties of the State were found by direct personal observation to contain the fungus. These counties are so well distributed over the infested area of Kansas as to leave but little doubt that those intervening are likewise supplied with fungus.

The widespread occurrence of Sporotrichum over the State was recognized near the close of Dr. Snow's investigations, in the nineties, since in one of his later reports (the fifth) we read the following: "We may conclude from the experiments that Sporotrichum was pretty generally prevalent throughout the State, and that probably in many localities there was no necessity for its artificial distribution in 1895."

The prevalence of the chinch-bug disease in Kansas soil once established, the next question was the practicability of sowing more fungus in fields known to contain it naturally. A solution was sought by actual field experiments in which relatively large quantities of fungus were used, sometimes on entire fields, other times on small plots where, in consequence, an intensive artificial application

of the infection resulted. While diseased chinch bugs were used to some extent in artificial infection, they proved inadequate because of the small amount of fungus available. Spore material for field work was generally obtained from cultures grown on a mixture of corn meal and potato extract. By the use of this medium large quantities of fungus were propagated in the laboratory. Its spores were tested from time to time in order to be assured of their power to produce disease in living chinch bugs.

With the exception of the experimental fields in one county (Anderson) there was already an abundance of Sporotrichum naturally present in the soil, as manifested by the whitened carcasses of its victims. These were generally in such large numbers and were so widely distributed that it seemed utterly futile to add any more fungus, since it was such a trifle by comparison. Nevertheless, 19 experimental fields, distributed over 5 different sections of the State, were treated with Sporotrichum spores. In some the artificial infection was confined to small plots of wheat 50 feet square, with the expectation that the intensive infection would start an epidemic of the disease that would spread and kill a large proportion of the bugs. But no results were forthcoming, for not only did the plots fail to become centers of contagion, but there was little or no appreciable difference between the treated and the untreated, or check plots, which were always used as a basis of comparison. General field infections were likewise always failures.

Considering the 19 localities as a whole, there were all sorts of conditions of humidity and rainfall, also character of soil. The results, however, were always the same—never at best any more than a slightly appreciable effect due to sowing spores and never more than a small percentage of the bugs killed. The bugs victimized by the fungus were as numerous in an untreated plot or field as in a treated one, the numbers bearing no relation whatever to artificial infection, but rather to climatic conditions, shade, moisture, etc. The evidence in every instance was overwhelming against the artificial use of fungus, as being without effect, and hence useless, since the fungus naturally found in the soil really accomplished whatever destruction of chinch bugs there was.

The third problem to be solved was the practicability of artificially treating a field with Sporotrichum when the fungus was shown to be scarce or, at least, ineffective. Three fields—one at Garnett, the others at Colony—were of this sort, and the bugs in all of them were liberally dosed with fungus. Small areas were treated as well as entire fields, and diseased bugs were used as well as culturally grown fungus; but scarcely any effect could be made, as measured by mortality among the bugs. No epidemic could be started nor the death rate appreciably increased, even in marked spots that were given specially large amounts of infection.

Conclusions from all the experiments may be summed up as follows:

1. The chinch-bug fungus is present naturally in fields everywhere throughout the infested area in Kansas.

2. It is present in such great abundance that any artificial distribution of infection in a field would be too insignificant, by comparison, to be of practical use.

3. Its distribution naturally through a field is much more uniform than any artificial distribution can be made.

4. The amount of fungus used experimentally in both wheat and corn fields was so far in excess of any that would be used by the farmer in infecting his own fields that he could not reasonably expect to succeed.

5. The fungus shows little tendency to spread from centers of artificial infection. The apparent rapid spread of the fungus is due to favorable conditions bringing it into activity simultaneously over considerable stretches of territory.

6. In fields where the natural presence of the fungus is plainly evident its effect on the bugs can not be accelerated to any appreciable degree by the artificial introduction of spores.

7. In fields where the fungus is not in evidence spores introduced artificially have no measurable effect.

8. Apparent absence of fungus among chinch bugs in a field is evidence of unfavorable conditions rather than lack of the fungus spores.

9. All the benefits of the Sporotrichum disease of chinch bugs may be realized by merely letting the fungus naturally present in the soil do the work of extermination as far as it will.

10. Moisture conditions have much to do with the appearance of chinch-bug disease in a field; artificial infection nothing.

11. Spent adult chinch bugs succumb to attack more readily than younger ones, but as the old bugs have finished depositing their eggs, their loss by fungus disease accomplishes little else than increasing the amount of the infectious material.

12. Laboratory experiments can be made to prove that artificial infection accomplishes results upon bugs confined in cramped quarters and without food, but in the field, where fresh and usually drier air prevails and food is abundant, an entirely different situation is presented.

13. Advocating artificial infection or encouraging it by sending out diseased chinch bugs does not serve the best interests of the farmer, since his attention is thus diverted from other and more efficient methods of combating the pests.

14. The reported successes of former years on the part of farmers are believed to be due to the following causes: (1) Failure to recognize spontaneous outbreaks of the disease because of previous arti-

ficial sowing of infection, and also failure to use check, or untreated, fields as a basis of comparison, thus claiming the outbreak as directly due to artificial infection; (2) failure to distinguish the skins of molted bugs from dead bugs; (3) mistaking the scattering of chinch bugs in cornfields for evidence of their death by fungus disease when carcasses were not present as proof.

Approved methods of combating the chinch bug.—The long-drawn-out fight against the chinch bug has brought to light many methods of combating it, which, when properly applied, have proved very beneficial; but the farmers are very busy men and can not devote a great deal of time to this work, and for this reason it seems best to speak only of methods which have proved the most practical. We can not hope to exterminate the chinch bug from any given district by any artificial methods now known; we must depend upon natural causes to do that, but in the meantime we can do much to stay their ravages. Their numbers can be greatly reduced and valuable crops protected from their depredations. The failure to control these and many other pests is not to be ascribed to the lack of practical means of control, but rather to the failure on the part of farmers and fruit-growers to avail themselves of the methods of control which have been worked out, and especially in the case of the chinch bug to the failure to secure concerted action throughout the area of infestation.

The two seasons when practical measures can be applied are: The fall, after the chinch bugs have gone into their winter quarters, and the summer season, at the time when the bugs are leaving the grain fields or immediately after they have massed themselves upon the first rows of corn.

Fall treatment.—Since the chinch bugs winter as adults in grassy places and in rubbish of all kinds, grasslands, and weed patches, every place where there is a possible chance for them to winter over should be burned off in the fall after they have gone into hibernation.

From observations made during 1910 while collecting bugs from their winter quarters, it was quite definitely determined that the bugs very much prefer bunch grass to anything else as a place to pass the winter, and where such grasses are growing along fences and roads adjoining cornfields they will be found to harbor vast numbers of bugs. So, if it is impractical to burn off all grasslands, those adjoining cornfields should, at least, be burned.

The burning does not necessarily kill the bugs, for they work down into the roots of the grass, where the heat caused by the burning is not sufficient to kill them, but those that escape the burning are left much more exposed to the effects of changes in temperature throughout the winter months and are likely to perish before spring. The drier the ground is when the burning is done the more effective will it prove, for when the ground is dry the grass will burn off closer

to the ground, more of the bugs will be killed outright, and the protection for those that escape will be more effectively removed. The burning should not be done too early, for in that case, unless every place where they might hibernate is burned, those bugs that escape destruction by the fire will have an opportunity, during the warm days that follow, to seek a new shelter. If the burning is delayed too long we are apt to have bad weather, which will interfere. About the latter part of November or the first of December is usually a good time. This is the time when there is a great need of concerted action. It will do little good for a farmer here and there to burn, if others do not. No consideration should prevent farmers all over the infested area from applying the torch in the fall or early winter.

Systematic burning is not to be recommended every year, for a large number of our most useful insects seek the same places to hibernate as the chinch bugs, but in years when the chinch bugs are apt to prove disastrous the good to be derived from destroying them in their winter quarters will by far outweigh the loss of some of our beneficial insects.

Burning in the spring will do little good, unless it should be very dry and the burning be done at just the right time. The only good that can result from burning in the spring will come from the bugs actually destroyed by the burning. If the burning be done too early, while the ground is still frozen, or later, when the ground and grass is very wet, very few bugs will be killed, but should the ground and grass be dry and the burning be accomplished between the time when bugs are beginning to come up out of the roots of the grass and move about, and before they begin their spring flight, large numbers will be killed. The most favorable time in the day for burning, either in fall or spring, is from 10 o'clock in the morning to 3 o'clock in the afternoon. If the burning is done in the night, as is often the case, the bugs will have descended into the roots of the plants again, and a smaller number will be killed outright.

Summer treatment.—After the bugs have become established in grain fields in the spring there is no practical way of destroying them. The best that a farmer can do is to hope for warm, wet weather during and following the hatching season in May and June, and prepare to take up the fight when they begin to leave the wheat fields. In making preparations for this fight the farmer should provide himself with a quantity of coal tar from the gas works, or No. 18 residuum asphaltum, or crude oil from the oil refinery, and either a knapsack spray pump or a spray pump mounted on a barrel. These should be provided before harvest begins, for sometimes they can not be procured without delay, and if this fight is to prove effective there must be no delay at the critical period.

The dust barrier.—The plan of the fight will necessarily depend on the conditions of the weather. If it should be warm and dry at harvest time the farmer should erect a dust barrier around the entire field containing the bugs, as follows: Before any of the wheat or other grain is cut, or, better, immediately after the first few rounds have been made by the binder, plow a strip around the field about 8 feet wide. This should be harrowed or dragged to pulverize the soil; then in the side of the strip farthest from the inclosed field a deep furrow should be thrown out with a lister, making round corners, and a log about a foot in diameter and 6 feet long, to which a single horse is hitched, should be dragged around the field during the day as long as migration continues. If it is very hot and dry many of the bugs will perish in their efforts to cross the dust barrier lying

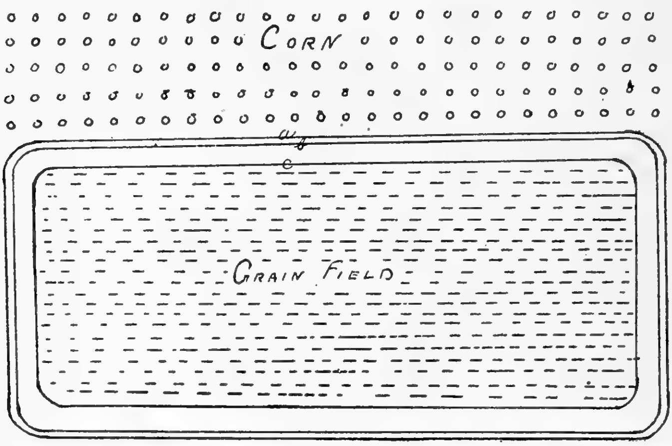


FIG. 3.—Diagram illustrating the construction of the dust barrier. *a*, Outer edge of dust barrier; *b*, furrow; *c*, inner edge of dust barrier. (Original.)

between the field and the furrow, and those which succeed in getting into the furrow will not be able to crawl up the dusty sides to get out. Many of them will be killed by the heat, and those that escape will be crushed by the log or smothered by the dust of the furrow. The log should pass along frequently enough to keep the bugs from making breaches in the dusty sides of the furrow by their constant endeavors to climb up. If one log does not prove sufficient two or three may be used, as needed.

If the weather should remain warm and dry during the whole time when the bugs are leaving the field the above method will be sufficient in most cases. This method, with perhaps a little difference in the details, has been found to be very effective, and has the advantage of being inexpensive and devoid of details which are necessary in other barriers, and it is, therefore, recommended when the weather is dry and hot.

Oil barriers.—If the weather should be wet, or if light showers should occur, so that it is not possible to keep the surface of a dust barrier pulverized and dusty, the farmer may resort to the oil barrier.

The type of the oil barrier used in past campaigns against chinch bugs is the earth ridge, with a small line of coal tar on top. It has been thoroughly tested, and if properly maintained will prove effective as a means of trapping and destroying the bugs in large quantities.

The plan found most effective is that of turning a double furrow with a plow, and thus forming a ridge, and putting tar, etc., on top of this ridge. On the side of the ridge next to the small grain, postholes about 75 or 100 feet apart and 2 feet deep are dug. The bugs are thus retarded in their march by the ridge, and, being repelled by the tar, etc., swarm along the ridge and crowd each other into the postholes. When the holes are nearly filled with bugs dirt should be thrown in and tramped down, and new holes dug to take their places.

After the ridge is thrown up by the plow the top should be smoothed off and packed down so as to hold the tar or oil which is poured thereon. The sides of the furrow should also be smoothed so as to make it difficult for the bugs to climb up. This can be done with a hoe and a rake, but it is much more quickly done by using a drag made with a concave bottom of the form of the desired ridge. This should be heavily weighted and drawn by horses along on top of the ridge. Such a drag is easily constructed and will save much time and do better work than can be done with the hoe and rake. The bottom of the drag will scour better if covered with sheet zinc.

Coal tar as it comes from the gas works is the best thing known for this type of barrier, as it does not sink into the ground readily and is very effective against the bugs. No. 18 heavy residium asphaltum from the oil refinery was tried as a substitute for the tar in one of our experiments conducted during the past season and gave excellent results. It stands next to coal tar in its efficiency, and costs about the same. It could be procured at the refinery last summer at $4 a barrel. It will require about one barrel of the tar or asphaltum for every 80 rods of barrier constructed. Crude oil was also tried, and while it was effective for a time after being applied, it soaked into the ground very readily and had to be renewed frequently. If crude oil is used, about twice the amount given for the coal tar will be needed. The cost of crude oil at the refinery (including barrel) was $1 in 1910.

Whichever one of the above repellents is used, it may be applied by using an old teakettle, coffeepot, or sprinkler with the perforated end of the spout removed. In applying the tar or asphaltum

the operator should move along fast enough so that the line deposited on the ridge is about an inch wide.

The ridge should be thrown up and the postholes dug before the migration begins, leaving the application of the repellent until actually needed.

The oiled-ridge type of barrier has the advantage of not being dependent upon a complexity of conditions for its success, and of giving immediate results. However, in dry, windy weather, when much dust is blowing, the dust is apt to stick to the tar or asphaltum in quantities to render it inefficient. For this reason the dust barrier is recommended for dry weather.

After the barrier is formed it should be inspected daily and kept in good repair. The tar will have to be renewed occasionally and the barrier kept free from straws or débris which might fall or blow

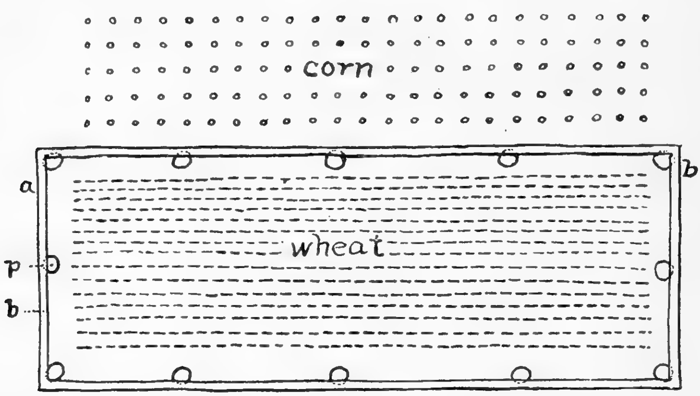


FIG. 4.—Diagram illustrating the oiled-ridge type of barrier—b, barrier; p, postholes. A partial barrier between the wheat and corn would extend from a to b. (Original.)

upon the ridge and form a bridge over the repellent stream for the chinch bugs to cross. Eternal vigilance will be the price of success.

The crude oil-straw barrier.—An experiment was tried in which straw dipped in crude oil was used as the repellent part of the barrier. It gave promise of success, especially when small fields were to be protected. To erect a barrier of this kind the farmer would need, besides the straw and crude oil, a tube or barrel mounted on a sled or wagon, a pitchfork, and a posthole digger. The oil is placed in the barrel or tub and the straw dipped into it and laid in a long windrow about a foot wide and from 4 to 6 inches high. This is the barrier. Postholes are dug on the wheat-field side of the barrier about 75 feet apart and so that the straw somewhat overhangs the edges of the postholes. Loose soil or air-slaked lime on the sides of the openings facilitates the fall of the bugs into the postholes.

The advantages of the oiled-straw barrier are its cheapness and the fact that it is not easily affected by weather conditions. Heavy

rains tend to wash the oil off, but it can be renewed easily with a garden sprinkler. Under ordinary conditions the original oiling will probably suffice.

The volatile products of the oil keep the bugs from crawling beneath the barrier, and the difficulty of crawling along straws lying in every direction and coated with the offensive-smelling oil discourages the bugs from their attempts to crawl over.

It is to be regretted that the oiled-straw barrier was not thought of soon enough to make a test of its practicability in protecting an entire field. A small patch of corn in a field into which the invasion of the bugs had already begun was surrounded by a barrier of this kind in order to ascertain its effectiveness. A few bugs were already in the corn inclosed by the barrier, but these were removed by hand and thrown outside. Any bugs that were subsequently found in the corn, therefore, presumably had crossed the barrier. The experimental corn patch lay in the direct line of march of the principal mass of migrating bugs.

The barrier was prepared June 23, 1910. During the next five days no fresh oil was applied, and a torrential rain washed out some of the oil with which the straw was originally saturated, leaving the upper straw odorless and reducing the oil beneath, so that the odor was faint. As a result, a few chinch bugs were found crossing the barrier on the uppermost straws. None was passing underneath. A second application of oil was made with a garden sprinkler. Had it been made immediately after the rain, probably no bugs would have crossed the barrier. No further application of oil was made. The field was inspected July 6. Only a trace of rain had fallen in the meantime, and the barrier had retained the odor of the oil, and consequently retained its effectiveness throughout the remaining period of the attack.

The bugs within the inclosure were so few in number that no material damage was done to the corn, and consequently the stalks had made a nearly normal growth and presented a striking contrast to the corn outside of the inclosure, which lay withered on the ground. No postholes had been dug, so that the insects encountered the barrier, passed around it, and then straight on into the corn beyond. A few, however, turned into the corn back of, and protected in part by, the inclosed patch. But as they did not damage it much, it grew and appeared nearly as vigorous as the corn within the barrier. By July 28 the chinch bugs had scattered, but they had left a trail of destruction in their path, all the corn being killed except the small patch protected by the oil-straw barrier and the corn immediately back of it and an occasional stalk here and there which had escaped serious injury. (See Pl. V, fig. 1.)

A barrier inclosing a field versus a barrier along one side only.—Barriers are usually erected only between the field from which the

bugs are about to migrate and the field to be protected. Such barriers are of value in preventing the injury caused by the massing of the bugs in the proximal side of the field into which the bugs are endeavoring to migrate, and by permitting destruction to a vast number of the invading host, but it should be remembered that when a field of grain that is infested with chinch bugs is harvested the bugs leave in all directions.

If the barrier is erected along one side of the field only, the bugs which escape from the other sides of the field manage to live on grasses and other vegetation, which usually can be readily found, until they get their wings, when they take wing and finally get into the corn. They not only injure it, but raise another brood, the adults of which pass the winter and come out in the spring to continue their ravages. Just before harvest practically all the chinch bugs in any community will be found in the grain fields, and if each one of the grain fields in the community were surrounded by an effective barrier such a large percentage of the bugs could be destroyed that the community would be rid of bugs in injurious numbers. If this could be done throughout the entire infested area there is little doubt but that the bugs could be successfully controlled and thousands of dollars' worth of damage prevented. However, a barrier along one side of a field is worth while and is to be recommended when for any reason it is not possible to erect it on all sides of the field.

Spraying.—It may happen that because of delay in getting an effective barrier up, the bugs get into the cornfield and mass themselves on the first rows. When this occurs the spray pump should be brought into use, and the bugs killed with kerosene emulsion or else with crude oil.

Kerosene emulsion.—The emulsion is made as follows: Dissolve 1 pound of laundry soap in 1 gallon of boiling rain water, then while hot add 2 gallons of kerosene, or coal oil, and stir vigorously with a stick for 10 minutes. The solution will soon take on a creamy appearance, but the stirring should be kept up for the full time. After the stirring is complete, from 27 to 47 gallons of rain water may be added according to the strength of the solution desired. By adding 47 gallons a 4 per cent solution is obtained, and Prof. Forbes and others have found this solution strong enough to kill most of the bugs and not injure the corn; but in our experiments this season we found that a 4 per cent solution did not kill the bugs to our satisfaction, and that the stronger solution, made by adding only 27 gallons of water, killed the bugs almost instantly and did not injure the corn to any extent when care was taken not to let the spray run down the inner circle of leaves at the crown. The important result to be obtained is the destruction of the bugs. As to whether the few rows of corn sprayed are injured or not, that is a minor consideration. If the bugs can be killed by the weaker solution and the corn saved, well

FIG. 1.—PATCH OF CORN PROTECTED BY THE OILED-STRAW BARRIER, AND SHOWING THE DESTRUCTION OF THE CORN OUTSIDE OF THE BARRIER. (ORIGINAL.)

FIG. 2.—CORNFIELD SHOWING CORN THAT WAS TREATED WITH CRUDE OIL. THE LARGE STALKS IN THE LOWER RIGHT FOREGROUND ARE IN THE ROW TREATED. (ORIGINAL.)

and good, but if the farmer finds that the bugs on the stalks sprayed are alive when examined an hour after being sprayed, he should use a stronger solution even if it does injure the corn.

Crude oil.—During the summer campaign an experiment was performed in Mr. Metcalf's field at Cherryvale, in which crude oil was applied directly to the cornstalks when they were badly infested with bugs. It was at first supposed that the oil might kill the corn; but it was found that, when applied to the lower portion of the stalks and the lower leaves, little or no harm resulted.

A field of corn lying north of a wheat field was exposed to a migration of chinch bugs. No barrier was used and consequently the bugs migrated into the corn. It was noticed that the great majority of the bugs were located on the stalks and lower leaves. A badly infested row was used for experiment and a checkrow, as yet uninfested, was treated in the same way. A bucket of crude oil was taken into the field and the oil dashed on the corn and the bugs with a bunch of coarse weeds gathered along the roadside. At the first stroke many of the bugs dropped to the ground, and the weeds were used to dash oil on them. Each hill in the row was liberally treated with oil and also the ground about the hill wherever the bugs were seen. The bugs were killed instantly and the oil protected the stalks from further attack. The two treated rows were watched for injury to the corn due to the oil. A personal inspection a month later showed no harm done, and a letter from the owner in the autumn declared that the rows matured corn in normal manner. The only precaution taken in applying the oil was to prevent the oil from getting into the crown of the young leaves. This method has not been tested thoroughly enough to warrant us in giving it our unqualified recommendation, but so far it has proved very destructive to the bugs and has not resulted in any material injury to the corn.

The use of sprays or crude oil should not take the place of barriers, but should be used as a supplementary measure only. (See Pl. V, fig. 2.)

The expense of making this campaign is very slight compared with the loss which the chinch bugs will occasion if not molested. The reasons mostly given by the farmers for not taking up this fight against the bugs is that they do not have time to bother with it. But if it is profitable to employ help to raise a crop it would seem that it ought to be profitable to put forth some little effort to save it after it is raised.

How to secure concerted action.—This whole subject needs to be agitated among the farmers. Township meetings should be called, the question discussed, and an organization formed for concerted action. At the first meeting called perhaps only a small number of farmers, the most progressive, will attend. With the organization formed, the agitation should be taken up by everyone interested. A time should be set for burning in the fall and efforts made to get

everyone to burn at that time. In the matter of summer treatment, the coal tar or crude oil could be ordered for a whole township at one time, resulting in a saving. Active preparation for the fight made by a large number before the time for the fight to begin will have a wholesome effect upon those who are lukewarm in their attitude toward it.

SUMMARY.

1. Organize by townships or school districts and counties.
2. Set a time for burning in the fall.
3. It it is not practicable to burn off all lands where there are weeds and rubbish, burn at least all lands where there are tufts of grass, and especially if they are in close proximity to cornfields.
4. Before wheat harvest secure a good spray pump and at least a barrel of coal tar or No. 18 residuum asphaltum for every 80 rods of barrier to be erected about wheat fields, or two barrels of crude oil for the same amount of barrier.
5. If the weather is dry at harvest time, erect a dust barrier around the infested field. Plow deep so as to cover completely all the stubble and trash, harrow and drag, then throw out a furrow near to the outside border, and start the log as soon as the bugs begin to migrate.
6. If rain should come, fix up a tar or crude oil barrier around the infested field.
7. Spray bugs that escape to the corn with kerosene emulsion or apply crude oil.
8. Keep up the fight as long as the bugs keep coming from the field.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 108.

L. O. HOWARD, Entomologist and Chief of Bureau.

LEAFHOPPERS AFFECTING CEREALS, GRASSES, AND FORAGE CROPS.

BY

HERBERT OSBORN,

Professor of Zoology and Entomology,
Ohio State University.

Issued September 12, 1912.

WASHINGTON:
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Nettie S. Klopfer, Ellen Dashiell, *preparators.*
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 12, 1911.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 108 of the Bureau of Entomology, a manuscript entitled "Leafhoppers Affecting Cereals, Grasses, and Forage Crops."

This matter was prepared by Prof. Herbert Osborn, professor of zoology and entomology in the Ohio State University, the best known American authority on these insects. Prof. Osborn was a temporary agent of the Bureau of Entomology, and spent about fourteen months in the work, visiting, during the warm months, various parts of the United States, and studying these insects in the field, on the farms and ranches, under natural conditions. He was able to devote his whole time to this work during this period owing to the fact that the board of trustees of the Ohio State University kindly granted him leave of absence for one year. We have, in this document, the first effort made in this country to determine the exact economic importance of these insects, together with the best methods of controlling them.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The present paper is designed to include the general discussion of the group of leafhoppers, with such matter as pertains to the group as a whole and with the consideration of the species which have been recognized as of the greatest economic importance. It deals on this account particularly with those species affecting the cultivated crops, although there are many species which live upon wild grasses and forage plants of the western ranges that undoubtedly have an important relation to the extent of the pasturage they may supply.

A second paper which is in preparation will deal more especially with the more technical aspects of the group, with a discussion of those species which are less noticeable as injurious species or which so far as at present known are confined to wild plants or to those of little cultural value. A knowledge of these is, however, important to economic entomologists, both for the sake of ascertaining their economic relations and as a basis for study in case they transfer their attacks to cultivated crops.

In the collection of material for these papers I have had the hearty interest and assistance of so many different individuals that I hesitate to attempt an enumeration of them, knowing that some must almost certainly be omitted. As stated elsewhere, the work was made possible by the interest of the officials of the Bureau of Entomology at a time when I had an opportunity to leave university duties, and for this interest and constant encouragement I am deeply grateful. At many localities and institutions where I worked I was given not only free access to collections and records, but the direct help of information as to available fields for observation and collection and often the advantage of personal direction and use of conveyances. In this way I am especially indebted to Mr. J. S. McGavren, of Missouri Valley, Iowa; the University of South Dakota; Prof. James Wilson, Brookings, S. Dak.; Prof. J. H. Sheppard, of the North Dakota Experiment Station; Prof. R. A. Cooley, of Bozeman, Mont.; Mr. George I. Reeves, of the Bureau of Entomology laboratory at Pullman, Wash.; Mr. W. J. Phillips, of the laboratory at Lafayette, Ind.; Prof. S. A. Forbes and Mr. C. A. Hart, of the University of Illinois; the Carnegie Museum, Pittsburgh, Pa.; Prof. H. A. Surface and Mr. V. A. E. Dæcke, Harrisburg, Pa.; Prof. Mel. T. Cook, Newark, Del.; Prof. Franklin Sherman and Mr. Z. P. Metcalf, Raleigh, N. C.; Prof. A. F. Conradi, Clemson College, S. C.; Mr. E. C. Cotton, Knoxville, Tenn.;

Prof. H. Garman, Lexington, Ky.; Mr. Harper Dean, San Antonio, Tex.; Prof. S. M. Tracy, Biloxi, Miss.; Mr. D. L. Van Dine, New Orleans, La.; Prof. A. E. Vinson and Dr. D. T. McDougall, of Tucson, Ariz.; Profs. C. W. Woodworth and W. B. Herms and Mr. Chas. Fuchs, at Berkeley, Cal.; Profs. E. D. Ball and E. G. Titus, at Logan, Utah; Prof. C. P. Gillette, Fort Collins, Colo.; Profs. T. J. Headlee and G. A. Dean, at Manhattan, Kans.; and Prof. S. J. Hunter, Lawrence, Kans. The collections at Cornell University, the Carnegie Museum, the Illinois State Laboratory of Natural History, Iowa State College (Ames, Iowa), the American Museum of Natural History (New York), the Boston Society of Natural History at Boston, the New Hampshire Agricultural College, the Bureau of Entomology, and the National Museum, as well as the private collections of many individuals, especially those of Mr. E. P. Van Duzee and Dr. E. D. Ball, have been freely at my disposal and have yielded many records of value.

A large number of the drawings have been made by the skillful hand of Miss Charlotte King, of Ames, Iowa; and some others, also of her drawing at an earlier period, have been used from the Iowa Experiment Station bulletins with the kind consent of the station officers.

H. O.

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LEAFHOPPERS AFFECTING CEREALS, GRASSES, AND FORAGE CROPS.

INTRODUCTION.

The question of the economic relation of the leafhoppers (Jassoidea) to the various cereal and forage crops has received some consideration, but, in the opinion of those most familiar with these insects, much less attention than their importance merits.

Several factors contribute to this neglect. One is that the work of these insects is so insidious, and its results, except where the insects occur in unusual numbers, so difficult to appreciate by ordinary observation that it is very likely to pass unnoticed.

Another is that the injury caused by these insects is very commonly charged to other agencies, either other insects, parasitic fungi, drought, or possibly even frost, because in many instances the insect itself escapes notice.

Again there are frequently so many species involved in the injury that there has been a tendency, even among entomologists, to consign them all to a limbo of undetermined species, with their habits, life histories, and food relations unknown.

The majority of the species are not only very inconspicuous, often protected by close resemblance to the objects around them, but they are very active, jump quickly when disturbed, are caught with difficulty except in a close-meshed net, and when in flight may be very readily taken for other insects except by a specially practiced eye.

Among many farmers they will pass as the "fly," which usually means the Hessian fly, and in recent years they have been very commonly called the "green bug," by mistaken reference to the Toxoptera, which has had such general notice in the daily press. In some localities, notably in the northwestern wheat-growing section, the term "green bug" has apparently been used very commonly for leafhoppers in the absence of the real Toxoptera.

Under these conditions it is evident that a thorough survey of the situation, an investigation for a number of crops and for all parts of the country to determine the economic status of the group, is desirable.

This is especially true because the means of control for these insects are for the most part to be based on entirely different grounds than for the Hessian fly, green bug, or other insects to which their injury is likely to be referred.

This question has seemed of importance to me for many years. In 1890, in a report to the Division of Entomology,[1] a number of species were treated for the central part of Iowa, and in several other papers issued while I was connected with the Iowa Experiment Station will be found discussions of the Iowa species with reports of some experimental studies in control. However, so many points remained undetermined and there seemed so much need of a general survey of the conditions for the country at large that it was a special gratification to have the matter taken up by the Bureau of Entomology and to be given the opportunity of devoting some time to the study. Coming at a time when the Ohio State University authorities had generously offered a year's freedom from teaching, it has been possible for me to visit many different States and to examine field conditions, collections, etc., and in this way to obtain a comprehensive view of the situation that would have been entirely impossible under other conditions, and which has brought to light some measures of control that it is hoped will be of distinct service.

This field survey has included, in the summer and autumn of 1909, trips through the northwestern wheat-growing and grazing sections of Minnesota, the Dakotas, Montana, Wyoming, Idaho, and Washington; parts of Ohio, Indiana, and Illinois; and Iowa, New York, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Tennessee, and Kentucky; and in 1910, Mississippi, Texas, Arizona, southern California, Utah, Colorado, Kansas, Iowa, Ohio, and Michigan, particularly the vicinity of Sault Ste. Marie.

SCOPE OF THE PRESENT INVESTIGATION.

The effort in this present work is to determine so far as possible the actual nature and extent of injuries to these crops by leafhoppers and the extent to which they form an economic factor, and to determine the conditions which affect their increase and destructiveness, the natural agencies which serve to keep them in check, and the possible basis for control by management of crops or application of direct remedies. The plan has been to make careful examinations of fields in the different regions visited, securing data so far as possible concerning previous history of fields or relation to preceding crops and to crops on adjacent fields, and to make extensive collections of specimens to determine the actual species present and the relative importance of these species to the crops concerned.

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[1] Bul. 22, o. s., Div. Ent., U. S. Dept. Agr., pp. 26–32, 1890.

NATURE AND EXTENT OF INJURY.

Like other members of the order of Hemiptera, such as the squash bug, the chinch bug, aphides, scale insects, etc., the leafhoppers secure their food and incidentally occasion injury to the plants they infest by sucking the juice of the plant. The mouthparts consist of a beak or proboscis, inclosing slender threadlike piercing organs which are thrust into the plant and through which the plant juices are drawn into the stomach. The result is a wilting or shriveling of the plant cells that are thus depleted of their contents, sometimes a curling of the leaf or the distortion of the adjacent parts, and in some cases a discoloration of the surface. This sometimes becomes a factor in protecting the insect, especially when the color of the insect and that of the plant cells is the same. Probably the most familiar examples of this kind of work are those of the wilting noticed following attacks of the squash bug or the chinch bug, the whitening of grapevine leaves by the grape leafhopper, or the coloring and curling of leaves infested by plant-lice.

On grasses and grains the attack is most commonly noticed in the form of wilted or discolored blotches on the leaves or stems. It was described by Webster as a combination of punctures and slitting. Sometimes, in bluegrass particularly, it results, as the writer believes, in the condition known as "silver top," a whitening of the entire upper part of stem and head, though this particular condition is in some parts of the country undoubtedly due to attacks of the grass thrips (*Thrips striatus* Osb.)[1].

Another relation to be noted is connected with the parasitic fungi that are frequently associated with the leafhoppers. It seems quite possible that these fungi may be assisted by the leafhoppers in their distribution or entrance to the plant tissues. In work on the sugar-cane leafhopper in Hawaii the insect is credited with increasing attacks of the fungus.[2]

The author was informed by the plant pathologist connected with the Bureau of Plant Industry, United States Department of Agriculture, however, that while certain saprophytic forms might attack the injured spots punctured by the leafhoppers, the truly parasitic species like the rusts invariably attack the healthy tissue in preference to injured places; the leafhoppers might, however, easily be an agent in the scattering of the spores over the plant and hence become a factor in the increase of injury from rust. It is often a matter of much diffi-

[1] See article "Silver top in grass and the insects which produce it." Osborn, Can. Ent., vol. 23, pp. 93-96, 1891.

[2] See "Fungus Maladies of Sugar Cane," by N. A. Cobb. Exp. Sta. Hawaiian Sugar Planters' Assn., Bul. 5, Div. Path. and Phys. Also "Rind Disease of Sugar Cane." Bul. 7, Hawaiian Sugar Planters' Assn. A similar condition is presented in the fungus rice blast, which, according to Mr. H. R. Fulton (La. Exp. Sta., Bul. 105, Apr., 1908), gains entrance to the plant tissue through punctures of *Œbalus pugnax* Fab.

culty to distinguish in deadened spots on the leaves whether the primary cause was insect or fungus.

Still another phase of injury is to be noted in the effect produced upon a seed crop by the attacks of leafhoppers on the blossom or the newly forming seed. Puncture of the unfertilized blossom will easily make the pollination useless, as will also the suction of a small portion of the sap from a newly set seed cause it to wither or prevent its maturity. Injuries of this sort in wheat, timothy, clover, alfalfa, etc., are probably of much greater frequency than we are aware.

Whatever view we may take as to the extent of damage and relative importance of these insects, all who have studied the subject will agree that the puncturing of the tissue and pumping of the plant juices must result in more or less loss and drain on the plant. The importance then will rest on the abundance of the insects that may attack any particular plant. It is evident that an insect which simply pumps away the juices of the plant may go on with this operation, constantly draining the plant and reducing its rate of growth. Still, unless passing the point where the drain begins to cause actual wilting, withering, or unhealthy condition, it may attract no attention from the cultivator. Nevertheless, this drain must show in reduction of crop, less available pasturage or forage, and actual loss none the less real because difficult to estimate in dollars and cents.

In some estimates based on the abundance of insects actually collected in given areas I have claimed that from 25 to 50 per cent of the growth of grass may go to feed these leafhoppers and still all this loss may occur without meadow or pasture actually showing by wilted or withered plants that such a drain was occurring. Only in periods of drought and when this loss may commonly be charged against a dry season is the effect such as to be noticeable in meadows and pastures.

Some idea of the number of these insects can be gained from various observations and counts and some appreciation of it by walking through a pasture or meadow and noticing the clouds of minute leafhoppers that spring into the air in one's pathway. Estimates based on various captures in Iowa resulted in from a half million to a million insects per acre. In tests of the hopperdozer in catching them, the writer secured in some instances more than a million per acre, and obviously this number must fall short of what were actually present. Some careful estimates based on actual captures over plats 5 yards square were made at my suggestion in the autumn of 1908 by Mr. V. L. Wildermuth, now an assistant in the Bureau of Entomology. These were in timothy and bluegrass-timothy pastures, and while it can not be assumed that all the leafhoppers occurring in the given area were caught, the average for all these captures gives us a result of about a million per acre. The detailed statement of catches and

proportion of different species is shown in the following table, kindly furnished for my use by Mr. Wildermuth:

Record of leafhopper sweepings in the fall of 1908, by V. L. Wildermuth.

Date.	Number per 5 square yards.	Number per acre.	Other species.	Deltocephalus inimicus.	Dræculacephala mollipes—mostly.	Dicraneura.	Chlorotettix.	Athysanus.	Phlepsius.	Cicadula.	Platymetopius.
Oct. 3:[1]											
First record	352	1,022,288	6	200	75	10	8	7	40	0	6
Second record	285	727,640	13	125	80	25	4	10	15	3	10
Average of two counts	318	874,964	10	163	78	18	6	8	28	$1\frac{1}{2}$	8
Oct. 13:[2]											
First record	370	1,174,480	10	200	50	30	15	20	30	5	10
Second record	571	1,658,184	10	385	30	35	20	18	40	8	25
Average of two counts	471	1,416,332	10	292	40	33	17	19	35	6	18
Oct. 18:[3]											
First record	748	2,172,192	15	596	2	74	0	2	19	36	4
Second record	538	1,562,352	10	425	5	50	0	3	25	20	0
Third record	653	1,896,312	20	500	1	100	0	5	15	10	2
Average of three counts	646	1,876,952	15	507	3	75	0	3	19	22	2
Oct. 25 (cool day):[4]											
First record	354	1,028,016	25	300	0	20	0	0	8	0	1
Second record	418	1,213,872	10	356	2	45	1	0	0	0	4
Third record	303	879,912	30	250	0	10	0	3	6	2	2
Average of three counts	358	1,040,600	22	302	1	25	$\frac{1}{3}$	1	5	$\frac{2}{3}$	2

[1] Lowland timothy, fairly short.
[2] Timothy and bluegrass, Ohio State University Farm.
[3] Upland timothy, grass eaten short.
[4] Upland timothy, grass fairly short.

CROPS AFFECTED.

While our survey is intended to cover the various cereals and forage crops, it must for a number of reasons be more complete for those that are of most general culture. In general, it may be stated that all of the crops belonging to the grass family and most of those in general cultivation belonging to the legumes are infested by one or another, often by many, species of the leafhoppers. The abundance and corresponding injury vary greatly with these crops for different parts of the country and under different cultural conditions, as also with different seasons, so much so that general statements for annual crops are hardly applicable here. One of the most obvious conditions, however, is that the greatest drain occurs where, owing to continuity of crops or by close association of common food plants, there is offered an exceptional opportunity for the survival and increase of the insects from generation to generation through a season or during a series of years.

For the wheat, oats, rye, and barley crops the most important species are, in the North and Northwest, *Cicadula 6-notata* and *Athysanus exitiosus*, and in the South, *A. exitiosus* and *Dræculacephala*

reticulata. For the grass crop, including timothy, brome grass, and bluegrass, the most important species are *Deltocephalus inimicus, D. affinis, D. configuratus, Dræculacephala mollipes,* and *Phlepsius irroratus.* For clover, alsike, alfalfa, soy beans, and leguminous crops the most important are *Agallia sanguinolenta* and *Empoasca mali.*

The fact that in many parts of the country their injury is negligible for such crops as wheat, oats, rye, etc., is due to the rotation or alternation of crops in such manner as to make their rapid increase impossible. On the other hand, the conditions existing in permanent pastures and meadows or that prevail where wheat, oats, etc., are grown closely adjacent to considerable areas of permanent grassland furnish favorable opportunity for their multiplication and migration, and serious injury must inevitably follow. One of the strongest contrasts in this line is furnished by the methods of wheat culture in the North and South. Throughout most of the spring-wheat section of the Northwest and the winter-wheat section of the northeastern United States the complete system of rotation or the absence of adjacent grass areas at the time when wheat fields could be infested renders injury from these insects almost unknown. In a number of the Southern States, however, the abundance of the grasses adjacent or the overlapping of the seasons permits a serious autumn infestation of the fields of winter wheat, rye, and oats and a consequent annual loss from this source. This is especially true of the Piedmont Plateau in South Carolina and Georgia, where the prevailing practice of terracing (see Pl. II, fig. 3) to prevent washing of the hillsides results in permanent strips of uncultivated and permanent grassland, including a mixture of many kinds of useless weeds. Furthermore, the size of the fields must be an important factor in the extent of infestation from adjacent fields and consequent injury. Where the fields cover hundreds or thousands of acres, opportunity for infestation is far less than where they cover but a few acres and are interspersed with permanent grasslands.

In the extensive stock-grazing regions of the central-western and northwestern United States where there are extensive permanent pastures, and notably the great area of wild grazing land (see Pl. III, fig. 1), both prairie and woodland, these insects have the best opportunity for production of successive generations each season and their number is limited only by the ability of the plants to sustain them or by the control affected by natural enemies, such as the parasitic or predaceous insects, spiders, birds, etc., that feed upon them.

DERIVATION OF OUR LEAFHOPPER FAUNA.

Inasmuch as several economic problems are dependent on a knowledge of the source of our present leafhopper fauna, it is desirable that this matter should be touched upon, although it must be admitted

that we are far from having sufficient data to warrant very positive conclusions. Nevertheless, the known facts concerning a number of the genera or subfamilies seem to point in certain directions and a cursory review of these would seem in place. If we compare, in a very general survey, the American with European or Asiatic leafhopper groups, we are perhaps first struck with numerous fundamental similarities, and, second, with the comparatively few cases in which there seems to be specific identity; a condition which would indicate common origin for the groups in general, and, further, a common development through a long period with a separation only long enough to result in the minor separations of species. While migrations may account for some of the agreements, there are many in which such explanation seems unwarranted—and we have a few cases in which a comparatively recent introduction seems quite certain.

In the genus Deltocephalus, which is practically of world-wide distribution, a comparison two decades ago might have led one to believe the genus essentially European, as more than a half hundred species are listed there. But within the last 20 years species for North America have been discovered and described in large numbers until now there are nearly a hundred known from the United States alone, a number which far outweighs the European showing and, if judged by number of species, we will be obliged to consider America as the home of the group and postulate a distribution from here to other geographic regions. Certainly the immense variety of forms with their wide range in latitude and altitude must be accepted as evidence of great antiquity. A great many of the species are boreal or alpine in distribution and while perhaps some allowance should be made for more extended collection and study in the North, it appears evident that the center of abundance and of variety of adaptation is to be found in the plain and plateau region of the Mississippi Valley and among the Rocky Mountains. From such a center the species diminish in number to the southward, few being known from Central America and South America. Dispersal then may have proceeded by northward routes to Europe and Asia, and southward through Central America and into South America. As for the species which have a common distribution in America and Europe it is as easy to assume migration from America to Europe as the reverse. *Deltocephalus abdominalis* Fab. and *D. minki* Fieb., which occur in northern Europe and America, may thus have migrated in one direction or the other, but our *D. debilis* Uhl., which may be a derivative from *abdominalis*, has apparently had its origin in this country.

In rather striking contrast to the Deltocephalus group we may take the genus Agallia, which, with some 25 or 30 species for America, shows a strong preponderance both in number of species and adaptation for environment in the southern United States and especially

in Mexico, Central America, and the West Indies. If we note the bare half-dozen species known in Europe, and the further fact that nearly all the species drop off as we pass northward in either region, we can best incline to the belief that this genus is essentially tropical or at least subtropical in its origin and that its dispersal has been northward into the northern United States and Canada and probably by an African route into southern Europe. If such be the case, it is interesting to note that a separation into certain types within the genus must have occurred before the migration, as the European species *Agallia venosa* Fall. and *A. puncticeps* Germ. parallel very nicely our groups of which *Agallia sanguinolenta* and *A. 4-punctata* Prov. are typical examples. Such a derivation possesses peculiar significance in connection with certain habits and life-history features, especially in modes of hibernation, and some of these may prove of fundamental importance in connection with efforts toward practical control.

Again, we have in *Athysanus exitiosus* Uhl. a species which has in all probability spread over the United States in very recent times, possibly even within the last half century, and which almost certainly had its dispersal from a tropical or subtropical center.

Another similar case, discussed more fully in another place, is found in *Dræculacephala reticulata* Sign., which is even now probably working gradually northward, though it seems from its present distribution to have a pretty definite climatic restriction.

SPECIES PRINCIPALLY CONCERNED IN DESTRUCTIVE ATTACKS.

Serious outbreaks upon different cereal crops are to be charged to a few species, notably *Deltocephalus inimicus, D. nigrifrons, Cicadula 6-notata, Dræculacephala reticulata, D. mollipes, Athysanus exitiosus,* and *Phlepsius irroratus,* all of which are among the most important from an economic point of view. There are numerous other species which attack these crops, especially various grasses and forage crops, the habits of which are important, but whose injuries individually are of less consequence than for the species just cited. In the case of the wheat crop serious attacks in America are to be charged against the few species above mentioned, all of which, except one, are native to this country; hence, not original wheat-feeding species. They seem, however, to find this plant an attractive food and where conditions permit will gather upon it in very destructive numbers and cause serious injury. Comparatively speaking, very few of the old-world species in this group have followed the wheat plant to this country, and there is only one species common to both Europe and America that can be considered a pest. Whether this species has been introduced since the introduction of wheat in this country is a question that probably can not be determined, since it is now so widely distributed that there is little evi-

dence pointing to the trend of its distribution. (See discussion under *Cicadula 6-notata*, pp. 97-99.)

It is extremely probable that some of the native species that occur in moderate numbers on various native plants have been stimulated by the introduction of cultivated crops which have furnished them a fresh food supply, so that they have increased greatly in numbers and have become of more importance from an economic standpoint than would have been true in their connection with native plants. Most of our species, especially those that attack cultivated crops, have a wide range of food plants. Some, however, are restricted very closely to certain genera or species of plants as hosts.

GENERAL HABITS.

There are several features in the general habits of these insects which may be discussed together, although there are certain ones in which each particular species must be considered by itself. In their food habits, as has been mentioned, there is a wide diversity, some species affecting a great variety of plants, others a very few. The various species, however, agree pretty generally in attacking the leaves or the freshly grown portions of the stem of the plant, making their punctures where they can secure the sap with the greatest ease, thus affecting the growth of the more succulent portions. In many instances the insect shows a distinct adaptation to certain parts of the plant, so that the shape and color of the body blends in with the part upon which it is feeding. This is the most noticeable in the case of certain species which are marked so that the colors blend with certain portions of the plant, notably in cases where this coincides with the markings at the joints of the stems, instances being known where such blending causes the most perfect resemblance of the insect to the joint. Some of the insects affect the seeds or blossoms, others cluster near the ground, and some have even been reported as affecting the roots, but this must be exceptional as very few have been noted to attack the plant in this manner. There is no distinct adherence to a particular plant except during the nymphal stages or for certain species which have aborted wings and are therefore unable to fly; practically all the species, however, jump with great facility and if disturbed will leave the plant and come to rest either on the ground or some adjacent plant.

General migration of the insects is not common, but there must be local migrations from field to field, especially at times when the food supply becomes scarce or unsuitable on account of the ripening of the plant. At such times we may have a general dispersal of the insects; for instance, from wheat fields to adjacent grasslands, or in autumn from grasslands to adjacent fields of fall wheat, oats, rye, etc., which furnish a much more attractive food for that season. Migrations in

any wide sense are unknown for any of the species. There has been observed in many cases a distinct tendency to gather at night around conspicuous lights, and while it is not known whether all of the species are thus attracted, so many different ones have been noted as being attracted by artificial lights that we may fairly presume that the habit is quite general. An instance was reported to the writer by Prof. Stedman, formerly of Missouri, with accompanying specimens of *Dræculacephala mollipes,* to the effect that this species gathered about lights at Columbia, Mo., in such numbers that they could be gathered up by the bushel. We have noted many instances of the appearance of the various species, including practically all of the more common, in rooms which are brilliantly lighted. This habit is sufficiently pronounced that it may be utilized for the purpose of collecting and destroying the adults before they have deposited eggs, although it has not been experimented upon to such an extent as to warrant any conclusion.

An interesting case of the assembling of these insects at Urbana, Ill., has been reported to me by my son, H. T. Osborn. He states that on the evenings of October 9 and 10, 1909, he noticed a cloud of insects about a cottonwood tree and upon examination found that these consisted largely of the *Phlepsius irroratus.* These were so numerous that he caught a net full, but no evidence of egg-depositing or of a particular object in this assembling was noticed.

The winter condition of these species varies, some of them passing the colder months as adults and in these egg-laying occurs in early spring; others hibernate as partially grown nymphs; and in other species, particularly the grass-infesting forms, hibernation is apparently common in the egg stage. This matter of hibernation is of the greatest importance, especially in connection with methods of control based on the treatment that is possible in late autumn and in early spring. It also is related to the effects of climate, as in the case of those forms which become active in mild weather during winter and are thus exposed to conditions which may affect their survival and the consequent injuries the following season. Another general habit which is of importance is a tendency to dispersal from one kind of plant to another during the last nymphal stage. It has been noticed that many species which seem to be very closely restricted to particular plants in the earlier nymphal stages, during the last nymphal stage scatter freely to different kinds of plants, showing a distinct disposition to vary their diet.

LIFE HISTORY IN GENERAL.

All of the species of leafhoppers pass through a series of molts, usually four or five in number, and in these various stages they show a gradual progression toward the adult form. In some cases these

early forms are sufficiently like the later and adult stages to be recognized, but more commonly there is sufficient difference in their appearance so that it is only by rearing them from stage to stage or by careful comparison of the different stages that it is possible to make out the correct life history. All, of course, pass through the egg and larval stages, and the last nymphal stage may be considered as corresponding to the pupal stage of insects in general. So far as has been determined the eggs in the species affecting grains and grasses are deposited in the leaves or stems of the food plants of the larvæ. The method of deposition has not been accurately noted in very many instances, but, for such as have been observed, it consists in the pushing of the eggs by means of the strong ovipositor into the margin of the leaf or into the spaces between the leaf and the stem so that the eggs are protected either by a covering of epidermis or by the thin leaf-sheath surrounding the stem. A good example of the method of egg deposition is found in the case of the shovel-nosed leafhopper, which is figured on page 66. The number of eggs deposited by an individual is known in a few cases and probably varies with different species. In some cases it must be considerable, as the rate of multiplication is rapid. The hatching of the eggs takes place either in a few days after the deposition or, in the case of hibernating eggs, early in the following spring, and consists simply in the emergence of the larvæ, the eggs being broken open at the end nearest the opening into which the egg has been forced. The molting occurs at uniform periods and consists in the shedding of the entire epidermal covering, this usually remaining attached to the surface of the plant as a thin, transparent film. The insects increase in size and soon change from the light color of recent emergence to the dark intense color common to the species. The number of generations in each season is also a variable matter, but there are commonly two generations each season, in some probably three, and in a few it is known that a single generation occurs. This is, of course, an important factor in the economic importance of the species since each additional generation provides for an immense increase of the numbers of individuals and also makes the special conditions of culture for the crop on which it feeds much less effective.

ECOLOGIC RELATIONS.

The leafhoppers constitute one element in a very complex relation of plants and animals, including birds, mammals, reptiles, toads, insects, spiders, etc., and it is only by the recognition of this relation that we can offer any very adequate explanation of their proper place in nature, and of their importance in the economy of cultivation. Primarily they are associated with certain kinds of plants upon which they depend for their sustenance, and the abundance of leafhoppers will be affected, necessarily, by the abundance of the food plant and

its availability as food material. An undue increase of the leafhoppers, which should result in the diminution of the food supply, must necessarily affect the possibilities of multiplication and cause a certain reduction in the number of the insects. This is, however, by no means the only statement of conditions as, aside from these two forms which may be associated in the same area, a large number of other organisms, both plant and animal, will affect the problem. The occurrence of different birds and predaceous insects which prey upon the leafhoppers will naturally reduce their numbers and to that extent favor the plants which serve as their food, whereas the presence of herbivorous animals, grasshoppers, cutworms, etc., serves to reduce the available food supply. Aside from these dominant forms there are also various fungus parasites which attack both insects and plants and which play their part in the complex of which the leafhoppers are such a conspicuous element. Furthermore the minute insect parasites which attack the leafhoppers add their part, tending to keep the latter reduced in numbers. The relation of these and other direct parasites which concern them may be considered under the general head of natural enemies.

NATURAL ENEMIES.

That leafhoppers maintain a fairly average abundance from year to year, for the most part causing no perceptible devastation, is due to the fact that there are so many different natural agencies tending to reduce their numbers or to keep them in check. Of these natural enemies birds, spiders, and predaceous and parasitic insects are probably the most important and require careful consideration.

It seems improbable that leafhoppers are affected to any great extent by mammals, except as eggs may be swallowed by foraging species—cattle, sheep, etc. The only forms which would seem likely to feed upon them are the moles and these confine their work so largely beneath the surface of the ground that it is doubtful if they would secure many of the leafhoppers. There are no records to show any service in this direction.

BIRDS.

Birds would undoubtedly be thought of as an important factor in the natural control of leafhoppers. It would seem that they might feed very commonly upon these insects; and yet very little has been published in the way of correct determination or definite records of the kinds of birds which feed upon them, or the extent to which these leafhoppers enter into their normal food. The most complete records in this line are those accumulated by the Bureau of Biological Survey of the Department of Agriculture, which has for many years past been making a record of the contents of birds' stomachs. Besides the

published data concerning certain species of birds, that bureau has an immense collection of unpublished records and these have been very kindly put at my disposal for the purpose of this study. Practically all of the data here presented on this point were derived from this material. While these records do not, in most cases, give the particular kind of leafhopper which is fed upon by certain species of birds, it should represent, of course, the kinds of leafhoppers which were abundant at the time and place indicated. The birds, of course, make no discrimination between species, except as they might appear in numbers or prove an easier prey.

EVIDENCE AS TO THE RELATION OF BIRDS TO LEAFHOPPERS.

While at first thought we might consider birds as a most important element in control of these insects, a closer study reveals many reasons why they must depend upon them but little as a food supply. Even with this more conservative view in mind, however, the actual condition as represented by the records of the Biological Survey are rather disappointing since they show that for practically all of our common birds the leafhoppers constitute so small a portion of their food supply that birds very properly may be considered as almost negligible in any consideration of the natural agencies of control. It is, however, important, both as a matter of record and for the benefit of future workers, that the actual condition as indicated by these records should be made available, and I have endeavored to sum up, as briefly as possible, the results of an analysis of the figures obtained, and the table of records is appended.

According to the records consulted by me and later revised by the Biological Survey, there are 119 different species of birds among those examined by that bureau whose stomachs contained jassid remains in various proportions, from a trace to 80 per cent. But, putting all the stomachs together, we have only 770 which contained jassid material out of a total of some 47,000 stomachs examined, or less than one out of fifty.

Even for the species of birds showing jassids in their food, we have only 770 out of about 28,000 (about 1 in 40) stomachs which included jassid remains and for a large majority of these stomachs examined the jassid contents were but from 1 to 10 per cent, so that on a most liberal estimate we can claim about the thousandth part of the food of birds as being made up of leafhoppers.

However, this general average may not represent the actual condition of effectiveness, for some of our most common birds abound in pastures and meadows where leafhoppers occur, and a critical examination for such species is desirable.

In the first place we may eliminate practically all the waterfowl—loons, divers, gulls, terns, pelicans, ducks, geese, cranes, bitterns,

herons, etc.—since they usually frequent places where these insects are not abundant.

A few records occur for snipe and sandpiper and one for the spotted sandpiper indicating that this latter bird may feed quite extensively on leafhoppers—probably species occurring on grasses in marshy ground.

Of the grouse family, the habits of which would seem to make them fitted to secure some portion of jassid food, only a very few records show such diet. Out of 75 prairie chickens, now no longer a factor except for the plains region, only one had eaten jassids; but the one taken on a Nebraska prairie in October had jassid material for 40 per cent of its stomach contents. This would show distinct ability to feed on these insects when available. For the common quail or bobwhite, whose wide distribution and frequent abundance make it perhaps of greater interest for this family, out of 971 stomachs only 35 contained jassid fragments, and for these they constituted only a very small percentage of the food, usually from 1 to 7 per cent. What the quail might do, however, in the case of an abundance of material of the larger species is shown in a series of stomachs from Virginia, taken in autumn, which included numbers of *Oncometopia lateralis*.

For the partridge (*Bonasa umbellus*), one bird out of 423 had eaten one leafhopper (a tettigonid) or 1 per cent—a food ratio for the species of 1 to 42,300, but so far as open fields are concerned this bird is naturally not to be considered of importance.

We would not expect the larger birds of prey, hawks, owls, etc., to feed at all on such small insects, so it may be considered merely accidental that the Cooper's hawk, one bird out of 109, had eaten a froghopper (a cercopid), which constituted one-twentieth of its stomach contents. Possibly, too, this was contained in the stomach of some other animal eaten by the hawk and, being less easily disintegrated in the process of digestion, remained as a fragment in the stomach.

The woodpeckers certainly would not be expected to prey on these insects, and for only one species, the downy woodpecker (*Dryobates pubescens*), is there any record, and that for only two birds out of 750.

Stomachs of Allen's humming bird, of the Pacific coast, show a record of 1 in 3 with 22 per cent jassid food; but this is offset by 88 per cent of spiders, which would suggest that the jassids were secured when in the grasp of spiders; another western hummer, *Calypte anna*, shows 10 in 111.

The nighthawk is distinctly insectivorous and as jassids are more or less on the wing at night these would seem open to attack, but the record shows only 22 birds out of 250 to have fed on them and the ratio of these to other insects to be very small. One or two exceptional cases would indicate captures during some extensive flight of jassids.

The chimney swift, a distinctly insectivorous bird, shows 13 out of 139 to have eaten leafhoppers, but one of these showed 50 per cent jassid material.

The flycatchers, which are preeminently insect feeders and active in the meadows and pastures, show, nevertheless, a very small leafhopper diet. The best record is for a California species (*Empidonax difficilis*) for which 11 birds in a total of 148 had eaten leafhoppers and in proportions as high as 73 per cent. Among our eastern species, only 3 birds in 91 of the yellow-bellied flycatcher (*Empidonax flaviventris*) had eaten leafhoppers, and in the proportion of 3 to 15 per cent.

Traill's flycatcher (*Empidonax trailli*) shows 5 in 134 with proportion for these up to 10 per cent, the Acadian flycatcher (*E. virescens*), 3 in 93 with 10 per cent for two, and least flycatcher (*E. minimus*), 4 in 162 with 10 per cent of jassid material in two and 20 per cent in one. The record for these four eastern flycatchers which might be expected to be especially serviceable shows, therefore, all together only 15 out of 480 stomachs to include jassid material, and the average for these can not be estimated as more than 10 per cent, so that the ratio of jassid diet would be only 1 to 500, or one-fifth of 1 per cent. The best that can be claimed for them, therefore, is that in case of excessive numbers of leafhoppers they might help a little in their destruction.

Even less useful in this connection are the phoebe and pewee, showing only about 2 to 100 with jassid contents, though two stomachs contained, one, 88 per cent, and another 100 per cent. The common kingbird, so universally present in fields, shows still less, 6 in 634, one bird, however, showing 52 per cent.

One of the best showings is made by a California species, *Myiarchus cinerascens*, for which 7 out of 90 birds had eaten jassids and in proportions as high as 94 per cent, while the eastern crested flycatcher (*Myiarchus crinitus*) shows again only 3 in 244 and a proportion of 5, 15, and 50 per cent.

Among the family of orioles and blackbirds, the cowbird shows the best record as a jassid feeder, there being 25 stomachs out of 590 with jassid contents, and for these 25 the proportion varies from a trace to 61 per cent, the average percentage for the 25 stomachs being 18.5 per cent—a food ratio of approximately 1 to 128; that is to say, 1 bird out of every 23 had eaten jassids to the extent of nearly one-fifth of his bill of fare. It is fair to assume that many of the birds showing no jassid diet were taken at times or places where this food was not available, and on this basis we can fairly credit the cowbird with good service—the best apparently of any of the birds for which data have been examined except the sharp-tailed sparrow.

The California redwing (*Agelaius gubernator*) shows a quite excellent record of 12 to 200, but our eastern species (*Agelaius phœniceus*)

only 7 in 1,150; the purple grackle or crow blackbird (*Quiscalus quiscula*) only 10 in 2,384, and these either but a trace or very small percentage, and the common meadowlark, a most familiar field resident, shows no record at all of eating Jassidæ, but two birds out of 1,157 had eaten cercopids to the extent of 5 per cent and 2 per cent. The Baltimore oriole (*Icterus galbula*) gives 1 in 207, but this one contained 88 per cent jassids. The orchard oriole (*Icterus spurius*) 3 in 153, and the Bullock's oriole (*Icterus bullocki*) 6 in 293.

In the sparrow family there are many species which from constant occurrence in fields have a distinct interest in this connection. While primarily seed feeding, it is known that many of them frequently include insects in their diet. None of the stomachs, however, except possibly the sharp-tailed sparrow, shows a sufficient amount of jassids to indicate that the members of this family are of any consequence as a check for these pests.

The lark sparrow shows only 5 in 257 and very small percentages in these five; the sharp-tailed sparrow 4 in 44, and *Passerherbulus maritimus* 2 in 31; the swamp sparrow, 2 in 72; the Lincoln sparrow, 4 in 42, and the common song sparrow, 12 in 714; the savanna sparrow, 3 in 300; the spotted bunting (*Pipilo m. montanus*) 2 in 150; the vesper sparrow, 2 in 140; the field sparrow 4 in 240, and the tree sparrow 2 in 555. The field sparrow shows 4 in 250, but these four are high, two being credited with 100 per cent jassids.

The sharp-tailed sparrow, with 4 birds out of 44, shows percentages of 80, 80, 75, and 30, or an average for the four of 66⅔ per cent, or a ratio for the 44 birds of 1 to 17, or 6 per cent jassid food, which is the highest percentage we have noted for any species and shows no records of spiders eaten.

The next best of these records, 4 in 42 or 1 in every 10½ for the Lincoln sparrow, with percentages of 4, 15, and 24, applies to one of the less common birds, and when the proportion of jassid material is noted gives us only 1 to 100 as the real ratio of leafhopper food to be credited to this bird.

Two of the swallows, the violet-green swallow and the bank swallow, show considerable numbers, but these are doubtless from cases of unusual flight. The good record of the marsh wren is offset by the fact that it must be of little service except in swampy places, but the Bewick wren, if a more common bird, would make a very good showing.

One of the nuthatches, *Sitta pygmæa*, as will be seen by the table, has a very striking record of 18 stomachs out of 32 birds with several containing 100 per cent of cercopids, but this is a Pacific Coast species and the tree-feeding habits of the bird exclude it from any probable service in grass or grain fields.

It is clear, if any conclusions at all are warranted from the mass of evidence here available, that it is useless to depend on birds for

control of these insects. No amount of "encouragement for the birds" or efforts to utilize their service in this direction can be expected to have any appreciable effect in reducing the number of leafhoppers, and we may dismiss this idea and turn our attention to other more hopeful agencies.

It should be kept in mind distinctly that these conclusions refer only to the relation of birds to this particular class of insects and must not be used as an argument for or against the status of birds in relation to the control of insects in general or of any other group of pests. The writer is fully aware of the important service that is rendered by many of our common birds in the control of a number of serious insect pests and would by no means wish to contribute to any undervaluation of their service.

The following list, with the leafhopper species arranged in alphabetic order, shows the species of birds which have fed upon leafhoppers, the number of stomachs containing such material, with the total number of stomachs examined for each species and the percentage for each record, as very kindly revised and corrected up to January 1, 1912, by the Biological Survey.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families.

FULGORIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Chætura pelagica	Fulgoridæ	137	2	1, 1.
Chordeiles virginianus	do	266	4	2, trace, 1, 1.
Otocoris alpestris	do	1,159	1	9.
Pyrrhuloxia s. texana	do	74	1	5.
Chordeiles virginianus	Oliarus aridus	(1)	1	12 (12 spm.).
Colinus virginianus	Scolops maculosus	971	1	2.
Lophortyx californicus	Scolops sp	619	1	10.

CERCOPIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Accipiter cooperi	Cercopidæ	100	1	Trace.
Chamæa fasciata	do	170	1	12.
Geothlypis trichas	do	130	1	30.
Iridoprocne bicolor	do	164	1	10.
Melospiza melodia	Cercopidæ (1 with 5 spm.)	718	3	15, 5, 100.
Otocoris alpestris	Cercopidæ	(1)	2	12, 20.
Quiscalus quiscula	do	2,384	1	2.
Sturnella magna	do	1,157	2	5, 2.
Penthestes atricapillus	do	644	3	50, 79, 90.
Polioptila cærulea	do	39	2	30, 20.
Setophaga ruticilla	do	17	2	81, 50.
Sitta pygmæa	do	32	18	100, 88, 100, 20, 79, 83, 90, 100, 77, 25, 50, 72, 45, 100, 100, 100, 85, 65.
Thryomanes bewicki	do	153	1	6.
Chordeiles virginianus	Aphrophora sp	(1)	1	Trace.
Chordeiles virginianus	Clastoptera xanthocephala (12 specimens.)	(1)	2	Trace, 1.
Junco aikeni	Ptyelus sp	1	1	40.

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

TETTIGONIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Hylocichla guttata	Tettigonidæ	460	2	70, 5.
Bonasa umbellus	....do	423	1	Trace.
Cardinalis cardinalis	....do	496	2	50, 12.
Myiarchus crinitus	....do	244	1	15.
Sayornis phœbe	....do	353	6	7, 25, 15, 6, 30, 25.
Muscivora forficata	Aulacizes irrorata	128	1	30.
Chordeiles virginianus	Dræculacephala reticulata	(1)	1	9.
Colinus virginianus	Diedrocephala sp	(1)	4	1, 1, 1, 4.
Telmatodytes palustris	....do	59	1	2.
Chætura pelagica	Diedrocephala versuta	(1)	1	1.
Chordeiles virginianus	Dræculacephala mollipes	(1)	5	6, 10, 8, 1, 8.
Chordeiles virginianus	Dræculacephala reticulata	(1)	1	9.
Chætura pelagica	Dræculacephala sp	(1)	2	1, 10.
Chordeiles virginianus	....do	(1)	2	40, trace.
Chordeiles virginianus	Gypona octolineata	(1)	1	Trace.
Chordeiles virginianus	Gypona sp. (1 with 12 spm.)	(1)	2	2, trace.
Pediœcetes phasianellus	Helochara communis	52	1	5.
Colinus virginianus	Homalodisca coagulata	(1)	1	5.
Colinus virginianus	Oncometopia lateralis	(1)	11	Trace, 6, 1, 5, 3, 2, 2, 4, 5, 1, 3.
Pediœcetes phasianellus	Oncometopia lateralis (20 spm.)	(1)	1	5.
Sayornis phœbe	Oncometopia lateralis	(1)	2	61, 8.
Colinus virginianus	Oncometopia sp	(1)	14	5, 3, 3, 5, 1, trace, 3, 5, 5, 5, 1, 1, 1, 4.
Sayornis phœbe	Oncometopia undata	(1)	1	80.
Empidonax trailli	Tettigonia atropunctata	134	1	4.
Pediœcetes phasianellus	Tettigonia sp	(1)	1	3.
Chordeiles virginianus	Xerophlœa viridis	(1)	6	1, trace, 1, trace, trace, 1.
Planesticus migratorius	....do	1,126	1	1.

BYTHOSCOPIDÆ.

Chætura pelagica	Agallia 4-punctata	(1)	4	1, 4, 4, 1.
Otocoris alpestris	Agallia sanguinolenta	(1)	2	6, 15.
Lobipes lobatus	....do	66	1	80.
Chordeiles virginianus	Agallia sp	(1)	2	Trace in both.
Marila americana	....do	67	1	Trace.

JASSIDÆ.

Actitis macularia	Jassidæ	3	1	5.
Æronautes melanoleucus	....do	12	2	2, 2.
Agelaius gubernator	....do	200	12	1, 1, 3, 1, 7, 1, 2, 2, 7, 15, 25, 2.
Agelaius phœniceus	....do	1,150	7	5, 1, 1, 1, 2, 1, 1.
Aimophila ruficeps	....do	25	1	66.
Passerherbulus caudacutus	Jassidæ (1 with 12 spm.)	44	4	80, 80, 30, 75.
Passerherbulus maritimus	Jassidæ	31	2	15, 20.
Anthus rubescens	....do	36	2	20, 2.
Aphelocoma californica	....do	626	2	3, 1.
Archilochus colubris	....do	62	3	90, 35, 1.
Bartramia longicauda	Jassidæ (1 with 10 spm.)	160	2	5, 20.
Bæolophus bicolor	Jassidæ	74	1	35.
Bæolophus inornatus	....do	76	1	10.
Calypte anna	....do	111	10	50, 10, 60, 90, 90, 50, 94, 100, 50, 50.
Chætura pelagica	Jassidæ (1 with 50 and 1 with 40 spm.)	139	13	50, 1, 9, 1, 2, 3, 2, 2, 20, 3, 15.
Chætura vauxi	Jassidæ	3	2	3, 20.
Chamæa fasciata	....do	170	9	2, 10, 10, 2, 20, 35, 1, 3, 60.
Chondestes grammacus	....do	257	5	2, 5, 20, 1, 5.
Chordeiles a. texensis	....do	17	2	10, 7.

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Chordeiles virginianus	Jassidæ	250	22	10, 1, 1, 46, 1, 1, 47, 20, 1, 1, 3, 1, 3, 43, 1, 6, 1, 56, 1, 5, 15, 5.
Colinus virginianus	do	971	15	1, 1, 1, 1, 1, 5, 1, 1, 2, 1, 1, 2, 1, 5, 3.
Myiochanes richardsonii	do	162	4	4, 10, 22, 5.
Myiochanes virens	do	359	4	25, 22, 24, 74.
Ammodramus s. australis	do	170	7	20, 10, 15, 10, 25, 50, 5.
Cyrtonyx montezumæ	do	25	3	1, 1, trace.
Dendroica æstiva	do	116	18	25, 3, 20, 37, 73, 86, 40, 15, 15, 10, 15, 25, 4, 3, 30, 35.
Dendroica auduboni	do	385	21	2, 61, 5, 10, 80, 15, 2, 4, 6, 10, 15, 5, 6, 5, 5, 1, 5, 15, 6, 40.
Dendroica coronata	do	33	1	10.
Dendroica magnolia	do	11	3	4, 41, 10.
Dendroica townsendi	do	31	2	8, 3.
Dolichonyx oryzivorus	do	302	5	35, 33, 3, 5, 8.
Dryobates pubescens	do	750	2	6, 5.
Dumetella carolinensis	do	287	2	25, 10.
Empidonax difficilis	do	148	11	15, 44, 38, 15, 40, 45, 5, 12, 73, 10, 4.
Empidonax flaviventris	do	91	3	15, 8, 3.
Empidonax hammondi	do	6	1	7.
Empidonax minimus	do	162	4	10, 3, 10, 20.
Empidonax trailli	do	134	5	8, 10, 10, 2, 10.
Empidonax virescens	do	93	3	10, 10, 1.
Euphagus carolinus	do	132	1	10.
Euphagus cyanocephalus	do	399	8	1, 1, 1, 3, 1, 1, 1, 3.
Gallinago delicata	Jassidæ (12 spm.)	145	1	50.
Geothlypis trichas	Jassidæ	130	13	20, 15, 5, 85, 15, 45, 30, 40, 15, 8, 2, 25, 50.
Vermivora celata	do	77	2	4, 81.
Vermivora peregrina	do	1	1	6.
Hirundo erythrogastra	Jassidæ (1 with 1,000 spm.)	331	23	1, 77, 1, 3, 20, 40, 5, 10, 4, 30, 48, 10, 4, 1, 1, 16, 10, 4, 3, 1, trace, 10, 7.
Hylocichla guttata	Jassidæ	(1)	6	16, 5, 1, 1, trace, 6.
Hylocichla mustelina	do	162	1	Trace.
Hylocichla ustulata	do	385	7	1, trace, 2, 2, 7, 5, 10.
Icterus bullocki	do	293	6	1, 6, 2, 8, 1, 5.
Icterus galbula	do	207	1	88.
Icterus spurius	do	153	3	1, 20, 10.
Iridoprocne bicolor	do	164	8	70, 3, 5, 6, 1, 2, 79, 35.
Junco hyemalis	do	553	11	75, 25, 35, 10, 20, 20, 20, 30, 5, 50, 30.
Lanivireo solitarius	do	47	10	80, 15, 15, 20, 10, 92, 20, 10, 20, trace.
Lophortyx californicus	do	619	6	1, 1, 2, 1, 1.
Mimus polyglottos	do	119	1	1.
Megaquiscalus major	do	121	2	Trace, trace.
Meleagris gallopavo	do	16	1	Trace.
Melospiza georgiana	do	72	2	65, 75.
Melospiza lincolni	do	41	3	25, 15, 4.
Melospiza melodia	do	718	12	10, 35, 70, 20, 1, 10, 25, 5, 50, 5, 6, trace.
Molothrus ater	do	590	25	2, 31, trace, 4, 15, 1, 28, 20, 1, 25, 61, 10, 29, 2, 4, 60, 8, trace, 1, 6, 7, trace, trace.
Muscivora forficata	do	127	1	6.
Myiarchus cinerascens	do	90	7	10, 10, 94, 7, 15, 30, 3.
Myiarchus crinitus	do	244	3	5, 50, 15.
Nannus h. pacificus	do	13	1	15.
Oporornis philadelphia	do	2	1	70.
Otocoris alpestris	do	1,159	14	30, 2, 8, 5, 60, 15, 40, 1, 20, 35, 12, 15, 5, 2,

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Passerculus sandwichensis	Jassidæ	300	3	35, 50, 15.
Penthestes atricapillus	do	344	3	20, 55, 6.
Penthestes carolinensis	do	82	1	2.
Penthestes gambeli	do	11	1	30.
Penthestes rufescens	do	61	4	11, 74, 47, 40.
Petrochelidon lunifrons	do	211	30	1, 1, 15, 83, 40, 10, 35, 15, 35, 1, 67, 15, 1, 6, 20, 2, 15, 20, 10, 15, 20, 15, 5, 5, 40, 6, 15, 40, 20.
Pipilo f. crissalis	do	400	9	1, 1, 1, 9, 43, 20, 4, 2, trace.
Pipilo maculatus	do	147	2	10, 1.
Planesticus migratorius	do	[1] 1,126	5	1, 1, 3, 1, 3.
Polioptila cærulea	do	39	6	40, 5, 65, 50, 30, 40.
Polioptila californica	do	31	9	75, 30, 20, 20, 30, 40, 40, 40, 50.
Poœcetes gramineus	do	32	2	5, 3.
Psaltriparus minimus	do	354	8	44, 7, 2, 15, 45, 15, 75, 7.
Pyrrhuloxia s. texana	do	74	1	3.
Quiscalus quiscula	do	2,384	10	1, 20, 2, trace, 1, trace, 6, 14, 3.
Regulus calendula	do	300	47	88, 82, 1, 10, 25, 25, 50, 5, 93, 70, 25, 40, 25, 98, 30, 48, 82, 12, 98, 18, 15, 8, 15, 40, 20, 10, 5, 25, 50, 55, 25, 6, 65, 41, 45, 45, 25, 20, 54, 35, 43, 78, 25, 5, 25, 10, 20.
Regulus satrapa	do	9	1	50.
Riparia riparia	do	238	19	20, 94, 10, 15, 6, 5, 4, 40, 5, 1, 6, 30, 88, 2, 68, 46, 3, 5.
Sayornis nigricans	do	343	4	5, 1, 1, 40.
Sayornis phœbe	do	353	6	5, 25, 100, 88, 25, 10.
Sayornis sayus	do	110	3	2, 7, 40.
Selasphorus alleni	do	3	1	12.
Selasphorus rufus	do	61	2	80, trace.
Setophaga ruticilla	do	14	1	90.
Sialia currucoides	do	52	1	1.
Sialia m. occidentalis	do	215	2	1, 1.
Sialia sialis	do	745	1	2.
Spizella passerina	do	302	3	10, 23, 5.
Spizella monticola	do	555	2	1, 5.
Spizella pusilla	do	250	4	10, 50, 100, 100.
Stelgidopteryx serripennis	do	35	1	15.
Sturnus vulgaris	do	114	2	40, 1.
Tachycineta thalassina	do	80	25	40, 5, 45, 30, 3, 8, 5, 20, 15, 20, 40, 20, 15, 40, 89, 20, 10, 10, 15, 15, 25, 45, 15, 10, 50.
Telmatodytes palustris	do	59	9	20, 20, 100, 15, 35, 40, 25, 2, 12.
Thryomanes bewicki	do	152	17	40, 50, 1, 5, 63, 45, 10, 15, 97, 40, 20, 25, 10, 10, 4, 1, 25.
Lanius ludovicianus	do	210	1	100.
Troglodytes aëdon	do	108	4	5, 10, 1, 70.
Tympanuchus americanus	do	77	1	40.
Tyrannus tyrannus	do	634	6	15, 3, 3, 2, 10, 52.
Tyrannus verticalis	do	116	1	14.
Vireo griseus	do	14	1	65.
Vireo huttoni	do	58	6	50, 69, 15, 40, 3, 96.
Vireo belli	do	8	2	6, 15.
Vireosylva olivacea	do	28	2	20, 3.
Vireosylva gilva	do	114	7	35, 10, 40, 1, 30, 7, 10.

[1] Recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Wilsonia pusilla	Jassidæ	67	11	67, 10, 50, 25, 33, 75, 15, 7, 60, 20, 15.
Xanthocephalus xanthocephalus	do	148	4	1, 1, 1, trace.
Zamelodia melanocephala	do	230	5	1, 4, 7, trace, 5.
Zonotrichia leucophrys	do	626	3	20, 15, 3.
Chordeiles virginianus	Acinoptera acuminata	(1)	1	2.
Chordeiles virginianus	Athysanus exitiosus	(1)	1	2.
Chætura pelagica	do	(1)	1	30 (12 spm.).
Chordeiles virginianus	Athysanus sp	(1)	1	Trace.
Chordeiles virginianus	Cicadula 6-notata	(1)	1	Trace.
Agelaius phoeniceus	Cicadula sp	(1)	1	5.
Chordeiles virginianus	do	(1)	3	Trace, trace, trace.
Molothrus ater	do	(1)	11	4, 3, 10, 2, 1, 1, 10, 1, 8, trace, 5.
Psaltriparus minimus	do	(1)	2	20, 1.
Chætura pelagica	Deltocephalus flavicosta	(1)	1	2.
Chætura pelagica	Deltocephalus sp	(1)	1	1.
Chordeiles virginianus	do	(1)	9	1, 12, 20, 5, 3, 8, 2, trace, trace.
Colinus virginianus	do	(1)	1	Not given.
Archilochus colubris	Empoasca sp	(1)	1	55.
Chordeiles virginianus	Eutettix sp	(1)	3	Trace in all.
Cyrtonyx montezumæ mearnsi	Phlepsius areolatus	24	1	1.
Chordeiles virginianus	Phlepsius cumulatus	(1)	1	1.
Chordeiles virginianus	Phlepsius excultus	(1)	1	1.
Chætura pelagica	Phlepsius irroratus	(1)	4	1, 1, 1, 8.
Chordeiles virginianus	do	(1)	8	10, 12, 2, 3, trace, trace, 1, trace.
Oxyechus vociferus	do	(1)	1	3.
Chordeiles virginianus	Phlepsius sp	(1)	1	1.
Chordeiles virginianus	Thamnotettix lusoria	(1)	2	Trace in both.
Chordeiles virginianus	Thamnotettix sp	(1)	2	Trace, 1.
Dendroica tigrina	Typhlocyba sp	(1)	1	8.
Vermivora peregrina	do	1	1	8.
Passer domesticus	do	421	2	100 per cent stomach nearly empty, 33.
Chordeiles virginianus	Xestocephala sp	(1)	1	Trace.

TETTIGONIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Larus franklini	Dræculacephala mollipes; Dræculacephala mollipes var. minor; Tettigonia sp	83	8	Trace in all.
		27,805	770	

[1] Number of stomachs recorded elsewhere in this list.

Reptiles and Batrachians.

The reptiles and batrachians are to be considered as a factor in the control of these insects, but there is little evidence of their being of much service, and except possibly for the frogs and toads, which are general insect feeders, there would seem to be little possibility of assistance from this group. Direct observations do not seem to show any evidence of the capture of leafhoppers by these animals, and in an elaborate record of the insects eaten by the common toad

given by Mr. A. H. Kirkland,[1] no record is given of leafhoppers having been eaten, but it is not stated whether the specimens examined came from meadows or grainfields where such insects were most likely to be taken. It is stated, however, that toads eat only active insects, and therefore they may not pay attention to the leafhoppers, which, except when disturbed, are very quiet. Moreover, as these animals feed mainly at night, the opportunity for them to capture leafhoppers would perhaps be much less than if they were feeding during the daytime. A special study of toads from meadows and pastures where leafhoppers are common would be an interesting addition to our knowledge in this line.

Insect Enemies.

The insect enemies for the leafhoppers are not so numerous as for some other groups of insects, but there are several which may be considered as of sufficient importance for notice.

Among the predaceous forms we have as the most abundant and efficient perhaps the little bugs of the family Nabidæ, some of which occur in great abundance in the meadows and pastures where the leafhoppers occur. The most abundant of the species is *Reduviolus ferus* L., which occurs throughout the entire range of the United States and may be found in almost every kind of grassy land. That it is a frequent predator upon the leafhoppers is indicated by its attack upon them when they are taken in the net, although it must be said that they are very seldom found with the insects actually impaled upon their beaks in the field. It is probable that this comes from their puncturing and sucking the blood of the insect very quickly and discarding the dead bodies so promptly as not to be found with them actually impaled. I have no question that they feed upon the leafhoppers as one source of their food supply, and believe them to be one of the principal agencies in keeping the leafhoppers in check.

Another group which is less notable is the genus Geocoris in the family Lygæidæ. These are minute flattish bugs with prominent eyes, and they occur as widely distributed common insects on the ground among the grasses and other low-growing vegetation. Their attack upon leafhoppers has been reported to me by various observers, and during the season of 1910 a definite record was furnished by Herbert T. Osborn of the Bureau of Entomology, for the species *Geocoris decoratus* Uhl. This, he states, was found at Wellington, Kans., in a number of instances with small leafhoppers impaled on its beak, and numbers of dead leafhoppers were found in the vicinity. The specimens submitted were *Empoasca flavescens* Fab. As this species of Geocoris is common over a wide range, it is doubtless serviceable in this manner in connection with many other species of leafhoppers.

[1] Bul. 46, Mass. Hatch Experiment Station, 1897.

The related species, especially *bullatus* Say, *uliginosus* Say, and *borealis* Dall, which are equally common over most of the country, certainly must contribute largely toward the reduction of the leafhopper pest.

PARASITIC INSECTS.

We have, in the parasitic insects affecting the members of this group, another most constant means of control, and one which is perhaps far more important than we readily appreciate. Among these forms are numbers of Hymenoptera, Diptera, and Strepsiptera. Of the Hymenoptera the most abundant parasites are included in the families Proctotrypidæ and Dryinidæ in the genera Gonatopus and Dryinus. These parasites affect the larvæ more particularly, but are often found upon the adults and are conspicuous, inasmuch as for many of the species the parasitism takes the form of an external sack-like structure in which the larva develops on material sucked from the body of the host. In some of our native species these parasites have been found present in something like 20 per cent of the individuals, so that it is evident that they must constitute a quite distinct check upon the leafhoppers. An extensive series of records showing the parasitism of these forms is found in the reports of the Hawaiian entomologist and in the papers of Perkins and others in connection with investigation of leafhoppers affecting sugar cane. Many species were collected and reared from leafhoppers occurring in the United States for the purpose of introducing them into the Hawaiian Islands in hopes that they might prove of service in control of the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirkaldy). A detailed account of these species would hardly be in place here, but the importance of this source of control is sufficient to make it worthy of further investigation.

Among the Diptera a genus, Pipunculus, is recorded as parasitic upon leafhoppers, and Giard is authority for the opinion that these are in general parasites, especially of the family Jassidæ. These have not been recognized to any great extent in this country, and we are unable to say to what extent they may have a service here.

The order Strepsiptera, or the twisted-winged insects, includes some very peculiar and remarkable parasites, numbers of which have been recognized as occurring on leafhoppers. These parasites are so minute and inconspicuous that they are very seldom observed, and we have no very positive data as to the numbers in which they may occur, so while they may be a very constant factor in control, it is doubtful if they can be credited with very much influence in reducing the numbers. The group is one of special interest on account of the peculiarity of structure and habit, and is one which may well be given much more extended study than it has yet received.

SPIDERS.

The great abundance of spiders in pastures, meadows, and grain-fields is often most manifest by the immense number of webs that may be seen, especially on dewy mornings. These webs, however, tell only part of the story as there are a great many species of jumping and running spiders which construct no web to capture their prey and among these there are to be counted some of the most numerous and active insect feeders of the fields. These spiders are often taken in large numbers when sweeping for leafhoppers and that they feed readily upon the hoppers is proven by finding them with hoppers in their grasp within a few seconds after their capture in the net. Direct observation on unconfined individuals is difficult, since both spiders and leafhoppers are so hard to watch, but enough has been seen to justify the opinion that spiders are among the most widely distributed constant and effective agents in keeping leafhoppers in check. Exact observations on particular species to determine their relative value as leafhopper feeders, and to learn as to the relative value of adults or young spiders in such captures and their relative attacks on young and adult hoppers would be of great interest. Very likely the younger or weaker hoppers are preyed upon, especially by the smaller species or the young spiders. Mr. J. H. Emerton, the well-known authority on spiders, informs me that many different species are useful in this manner and he has kindly indicated a number of the species that he believes to be most efficient in this manner. Among these are the *Xysticus triguttatus* Keys., a species especially abundant in grasses and well adapted for leafhopper capture, and the different species of the genus Misumena, which are abundant in grasslands and low vegetation even up to high altitudes.

The species of Philodromus are among the forms that construct no web, but capture their prey at large and are active feeders on leafhoppers. The genus Phidippus, including a number of species of the jumping spiders, are also very active in this work.

The species of Dendryphantes, especially *militaris* Hentz and *suturalis* are considered by Mr. Emerton as among the most active leafhopper feeders.

Mr. Nathan Banks, another well-known authority on spiders, has given me the following list of species which probably feed on leafhoppers:

Epeira trivittata Keys., one of the most common web-making species; *Oxyopes salticus* Hentz, which is very common in the South; *Thanatus rubicundus* Thor.; Phidippus, especially the young, and mostly *P. rufus* Hentz and *P. audax* Hentz; *Thiodina retaria* Hentz; *Tutelina elegans* Hentz; *Agelena nævia* Walck.; *Mangora gibberosa* Hentz or *M. maculata* Keys.; *Plectana stellata* Hentz; *Epeira pratensis* Hentz; *Tetragnatha laboriosa* Hentz.

When we consider the carnivorous habit and observe the immense numbers of spiders in the fields, and realize that in many cases leafhoppers are the most abundant and accessible food supply for them, it is easy to credit the spiders with immense service in this direction.

REMEDIAL MEASURES.

The various methods of control for leafhoppers may be discussed under the general head of remedial measures. Some of the particular modes of treatment, applicable to certain species and to particular conditions of culture, must be discussed in connection with the species concerned. Practically all of the measures available must be adapted for the seasons or conditions of crop and consequently to advise any general method, applicable in all cases, is impossible.

CULTURAL METHODS.

Under the head of cultural methods we may discuss the effect of different plans of cropping, or the rotation or alternation of different crops, and this is, in many cases, one of the most effective means in keeping leafhoppers in check. The general immunity of spring wheat, in the northwestern wheat-growing regions, is quite certainly due to the effect of the methods of culture prevailing there, which do not permit a general infestation of the wheat fields; as, during the time when the insects would scatter for the deposition of eggs, the fields to be planted in wheat are mostly bare and furnish no attraction for the insects. In the case of the northern wheat regions, as in Pennsylvania, another condition is evidently to be considered and this is extreme cleanliness of the culture, the fields being cultivated so close to the fences that scarcely any grassland remains, as is the case generally where the dispersal of the leafhoppers occurs. Another very evident condition is the accumulation of hoppers in fields which have been continually in grass for a number of years. In such cases they occur in immense numbers, even as high as a million or more to an acre and the resulting injuries become serious. Contrasting this with fields in grass only one or two years it appears quite evident that rotation tends to eliminate the leafhoppers and that it requires two or three years of continuous grass to give opportunity to the leafhoppers to reach their full numbers. In sections where there is a general plan of rotation so that grass occupies certain fields for not more than one or two years, injuries are restricted to such an extent that they may be ignored. A striking instance of this was noticed on the North Dakota Agricultural College farm (see Pl. II, fig. 1), where a pasture in brome grass (Pl. I, fig. 2) for several years was badly infested, while nearby fields recently planted in grass were nearly free. When permanent pastures are in woodland, where rotation is obviously impracticable, it is evident that other measures must be adopted in any control to be secured.

MOWING.

The possible control of the species by the cutting of the grass depends upon an adjustment of the mowing to about the time when the insect is present in the egg stage or at such an immature larval condition that it is unable to migrate from the fields; at such times close mowing of the grass will remove such eggs as may be included in the leaves or stems and by exposing the young larvæ to a shortage of food as well as to the direct action of the sun, serve very materially in their reduction. A somewhat similar effect may be produced by providing for the very close pasturage of the grasslands during a certain period, if possible to correspond with that of the egg deposition of the more common species, alternating with a period of absence of stock from the field so that the grass may have a period of rapid growth.

BURNING.

Undoubtedly one of the most effective means of destroying the eggs of the leafhoppers in autumn or early spring is the burning of the dead grass wherever this means is practicable, and it may be resorted to with the assurance that much will be accomplished. The difficulty in this treatment arises from the fact that some grasses will not withstand burning except when the ground is frozen or wet enough so that the heat will not penetrate the surface and that, in cases where fields are freshly seeded to grass, the young plants may be injured by this treatment. This process is, perhaps, most available in the prairie regions, where the accumulation of dry material at the surface of the ground furnishes abundant opportunities for the application of fire for the destruction of eggs and hibernating forms, occurring in the locality. It is also especially applicable to the alternating strips of grass, in the localities where wheat and grass are planted side by side. Direct observations on this plan have shown some good results, but it has not had general use under conditions giving accurate results. In the prairie regions, before general settlement, the prairie fires were of very common occurrence, and while we can not determine just how much they have accomplished in the control of these insects, it is worthy of note that pasturage on these plains was of a very excellent quality and of long duration. One of the most positive evidences of the effectiveness of burning came under my observation in the spring of 1910 in Ottawa County, Kans. On a level tract of grassland adjacent to a stream, part of the surface had been burnt over a short time previously and the burnt tract was practically free from leafhoppers while the adjacent unburnt area, under otherwise identical conditions, was abundantly infested with hoppers of several different species. Even where the areas examined were closely adjacent or the burnt patches were surrounded by unburnt grass the difference was very noticeable. This was evi-

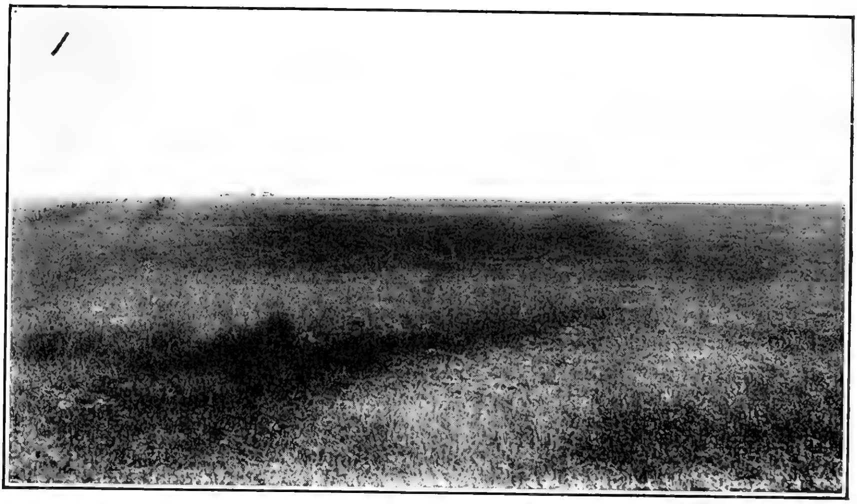
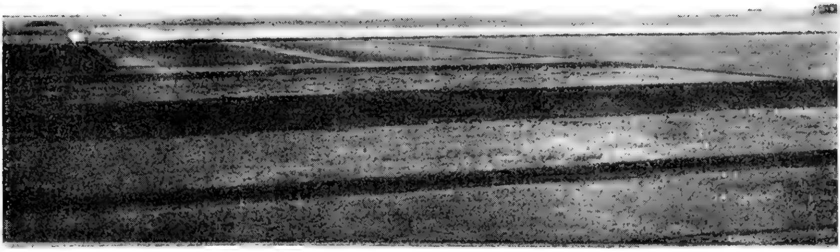


FIG. 1.—AN OLD MEADOW OR PASTURE NEAR ADA, MINN., WITH A MIXTURE OF GRASSES AND WITH FULL INFESTATION OF LEAFHOPPERS. (ORIGINAL.)

FIG. 2.—A BROME-GRASS PASTURE ON THE AGRICULTURAL COLLEGE FARM AT FARGO, N. DAK. IN GRASS FIVE OR SIX YEARS AND BADLY INFESTED WITH LEAFHOPPERS, ESPECIALLY DELTOCEPHALUS CONFIGURATUS. (ORIGINAL.)

1



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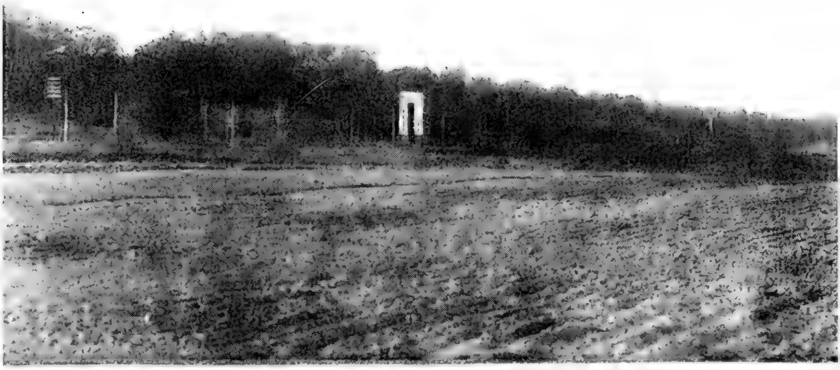

3

FIG. 1.—EXPERIMENTAL PLATS ON THE AGRICULTURAL COLLEGE FARM, FARGO, N. DAK.; NEW PLANTINGS AND WITH CLEAN ROADWAYS SEPARATING THEM FROM ADJACENT FIELDS. THESE PLATS WERE NOTABLY FREE FROM LEAFHOPPERS, ALTHOUGH FIELDS NEARBY WERE AFFECTED. (ORIGINAL.)

FIG. 2.—EXPERIMENTAL PLATS OF THE U. S. DEPARTMENT OF AGRICULTURE AT ARLINGTON, VA. IN AUTUMN WITH BUT NARROW SEPARATION FROM INFESTED GRASS PLATS OR STRIPS AND SHOWING CONSIDERABLE INFESTATION BY MIGRATION. (ORIGINAL.)

FIG. 3.—A TERRACED FARM IN SOUTH CAROLINA SHOWING THE UNCULTIVATED TERRACE STRIPS IN WHICH THE LEAFHOPPERS BREED AND FROM WHICH THEY READILY MIGRATE TO THE CULTIVATED CROP ON THE LEVEL. (ORIGINAL.)

dently on account of the quite recent burning and the fact that unfavorable weather had kept the hoppers so inactive that there had been little migration from unburnt to burnt portions. With so positive a case as this along with many others of nearly equal certainty it seems entirely warranted to recommend burning for such pasture lands and range as can be treated in this manner without detriment in other ways.

CAPTURING IN HOPPERDOZERS OR TAR PANS.

The direct treatment which has had the most thorough trial is the use of the hopperdozer, which consists of a sheet-iron strip coated with coal tar. The apparatus is drawn over the grass and the insects, hopping at its approach, fall upon the surface and thus many of them are killed. In a number of tests of this method at the Iowa Agricultural Experiment Station it was found that, in pastures ordinarily infested with leafhoppers, the insects could be captured at the rate of a half million to a million to the acre, which very appreciably reduced the number occurring in the treated fields. Probably three-fourths or more of the hoppers occurring in any particular area were captured by one or two treatments of this kind. It was found that this treatment could be applied to best advantage during the latter part of the afternoon on sunny days, when the insects would jump with the greatest facility and could be caught in the greatest numbers. In one experiment with this plan, two equal areas were treated for a season, and a comparison of the hay for the area showed an increase for the treated plat of more than 50 per cent. Two lots of bluegrass were used in an experiment, each containing about one and three-fourths acres. These were fenced. One plat was treated, leafhoppers being collected from it in large numbers at various times, and upon this plat cattle, varying in numbers, had been pastured at different times throughout the season for a period of about 73 days. On the other, untreated, a single cow was pastured. A comparison of the number of animals on each plat, taking into account their relation with the plat and the time during which they were pastured upon the area, shows that the treatment gave a gain of 68 per cent in the capacity of the pasturage. While this test may not be taken as an exact measure of the advantage to be gained in other cases, it should stand as an approximate gain for that test. However, it is evident that migration of these insects from adjacent areas would tend to reduce the advantage of the treatment, especially in a small tract, and that the greatest advantage could be secured from treating an entire pasture, so that there would be no opportunity for reinfestation from adjacent lands. The expense of this method of treatment is not great, it being estimated that in a section suitable for farm operations it may be easily performed at a cost of 7 cents per acre.

SPRAYING.

Since the perfection of spraying apparatus, it is possible to apply broadcast sprays of insecticides over any pasture lands or meadows, or even cultivated fields, where the crop is not so far advanced as to prevent access to the surface of the land. Such treatment, so far as the mechanical features are concerned, would be entirely practicable. At the North Dakota Agricultural Experiment Station such a broadcast sprayer is used for treatment of the fields to kill weeds and, using a kerosene mixture or emulsion, it would seem that very effective results on the leafhoppers could be secured.

SOME PREVIOUS RECORDS OF INJURY.

While actual records of appreciable damage are not abundant, there are a number which clearly show the possibility of destructive abundance and it may help to emphasize this to present a few such records. Most of these are in publications not now commonly accessible to most farmers, while some of them will probably appear new, even to professional entomologists.

One of the earliest records of this kind is for Illinois, 1875. Perhaps the most definite and fully reported is given in Prof. Comstock's report as Entomologist in 1879, which is given in full under *Cicadula exitiosa*. Another, from Orangeburg, S. C., November 20, 1893, reads as follows:[1]

> I send you to-day by mail sample of flies or insects which are infesting the small grainfields in this part of the country * * * 14 miles east of C. H. * * * and in some instances *completely destroys* the oats and rye. These insects appear in *great numbers* and when the oats and rye are just up they completely destroy it. After it gets a good root and begins to spread out they do not kill it out so bad but keep it from growing and it looks sickly and small. What is the name of the insect and how can we get rid of it? Under the glass it looks like a locust—can fly and hop. In young rye planted for grazing they are now in great numbers—millions—notwithstanding we have had several good frosts. I have been in several counties lately and I see them everywhere, but not so numerous as on my place. In some places they have destroyed the young turnips. * * *

A particular instance that came under the observation of the writer and was reported in Insect Life, Volume IV, page 197, 1891, occurred in the city of Washington on a newly planted lawn on the grounds of Prof. C. V. Riley, then the Entomologist of the department. In this case the effect showed very plainly in shrunken, withered plants in spite of abundant watering.

The bureau records include a number of more or less detailed reports for the country, usually without definite determination of the species causing the injury.

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[1] See Insect Life, vol. 6, p. 267, 1894.

Records of the Bureau of Entomology.

The records of the Bureau of Entomology made by Prof. F. M. Webster and his assistants, namely, Messrs. C. N. and G. G. Ainslie, E. O. G. Kelly, W. J. Phillips, G. I. Reeves, T. D. Urbahns, and V. L. Wildermuth, show the occurrence and more or less injury to crops in the following localities and for the crops mentioned:

At Huntsville, Ala., on wheat in the years 1905–6, the record for 1905 being November 5 "from a field of young growing wheat," and in this record, out of 222 insects taken 103 were jassids.

In Indiana Prof. Webster reported jassids on wheat at Lafayette in the years 1885–1891, and the records, especially for two of the species, will be mentioned farther on in reference to those particular species. At Osgood in 1890 he reported jassids as excessively abundant in fall wheat and that under the impression that they were Hessian flies the farmers reported considerable injury. A further report from Oxford in 1884 stated that *mollipes* occurred in oats and that in the second internode a cluster of larvæ was found. "Straw when grown did not seem to be withered or show any other effects except possibly premature ripening; searched assiduously, but found no others."

In Kansas jassids were reported at Concordia on wheat in 1905 and at Manhattan in 1907. They were abundant on young volunteer wheat. They were reported on September 8, 1908, at Wellington, the cast skins on wheat showing the development of the jassids on this plant. At Mulvane and at Sedgwick they were reported on March 26.

In Kentucky an infestation was reported at Fulton for 1905. In Nebraska they were reported for alfalfa September 1, 1909.

In New York two species, *Dræculacephala mollipes* and *Athysanus exitiosus*, were collected from bluegrass November 20, 1909. They occurred at the base of the grass.

In North Carolina jassids were reported as occurring on corn in the years 1907 and 1909. The work of *D. mollipes*, in the latter year particularly, will be referred to more in detail under that species.

In North Dakota they were reported as occurring on grasses at Tower City during the years 1905 and 1906.

In Oklahoma they were reported at Woodward on wheat in 1905, at Duncan on oats in 1908, at El Reno on wheat in small numbers in 1908, at Enid and at Stillwater as very numerous, and at Pawnee as occurring on both wheat and oats.

For Pennsylvania reports of their occurrence are given for Marion on bluegrass in 1909.

In South Carolina they were reported as collected on wheat in 1909, Mr. George G. Ainslie stating that in a field of wheat near the experiment station he found the grain swarming with one or more

species. Not having a net, he collected only two specimens. "There were spots and blotches on the fresh blades which may have been made by these bugs, but I was unable to catch any in the act. A movement of the grain raised a cloud of the hoppers." They were also reported for 1908 as occurring in numbers on barley and alfalfa at the same place and at Spartanburg on corn June 2 and 3. Reports of damage to cowpeas in 1908 and 1909 indicate serious injury. "The larvæ were in all stages and were found almost altogether on the underside of the leaves. A few were seen on the petioles. Usually not more than one was to be found on one leaf."

In South Dakota they were reported as affecting alfalfa in 1905.

In Tennessee there is a record of their occurrence on wheat at Union City in 1905 and at Knoxville on rye and oats in 1908. The record of occurrence on rye states that they were numerous in all stages on the small plants that had been cut and then stooled out. The jassids were on the leaves "way down into the crown of the plant." There is also a record for the occurrence on peanuts in 1908.

A number of records are given for the State of Texas, those for wheat being from Paris (1905), Arlington, Dallas, Corsicana, Greenville, and Whitesboro in 1908, and on oats for the same year at Arlington, Dallas, Corsicana, Greenville, and Whitesboro. There is a record for grass at Sinton, where it is stated that the jassids abounded everywhere upon Bermuda and other varieties of grass growing in damp places near the water tank and creek. At Denison, Tex., they are reported as occurring on barley, and the report states that a small field of barley, about one-fifth acre, had been killed outright a week or ten days previously by Toxoptera. No sign of the latter could be found, but there was an abundance of Jassidæ, all of one species. These were the prevalent insects at the time of the outbreak. This species was determined as *Cicadula 6-notata*. At Ringgold they were reported as numerous in one oats field and damaging the plants. The cast skins were numerous on the leaves (which would prove development on oats). On March 17, 1908, there were few adults. At Whitesboro on oats they were reported very thick, causing red spots to occur, the cast skins hanging to the leaves, but no adults among them. At Grand Prairie in September, 1907, they occurred on grass. At Dallas in 1909 they were infesting alfalfa and sorghum; in some cases they were very numerous and causing injury; in others no injury was apparent.

At Charlottesville, Va., they were reported on alfalfa for October 5, 1906. These were from an alfalfa field on the farm of E. C. Massie and from borders of the field also. Mr. Massie claimed that the alfalfa came up nicely and was almost at once eaten up; there is no absolute certainty that the species collected were concerned in the destruction of the alfalfa, but they were abundant in the immediate vicinity of the field.

At Pullman, Wash., wheat was infested in 1908 on the college farm, the reports referring particularly to presence in volunteer wheat.

In the District of Columbia there is a report for occurrence on clover in 1909, and also for the occurrence and rearing of adults of *Empoasca flavescens* Fab., *Deltocephalus nigrifrons* Forbes, and *Liburnia puella* Van D. from *Panicum proliferum.*

OBSERVATIONS DURING THE SEASON OF 1909.

During the season of 1909 it was possible for me to make observations in a great number of different and widely separated localities and this furnished a basis for comparison of the conditions in different parts of the country. A general summary of these comparisons may be instructive.

Starting in Iowa in the middle of June observations indicated but little injury from leafhoppers in the grain fields and only the ordinary amount of abundance in grassland—perhaps less than in many seasons on account of the lateness of the season and extremely wet weather conditions that had prevailed earlier in the season. In the Missouri Valley section wheat fields were practically free from jassids, as also from any indications of injury from aphidids, Hessian fly, or joint-worm. Fields of alfalfa intermixed with volunteer wheat and clumps of grass were infested with the usual species, but not in great abundance. In timothy, *Deltocephalus inimicus* was present but in moderate numbers. Farther north, at Vermillion, S. Dak., these species were present in wheat fields, but usually where some grass was present and there was little indication of direct infestation of spring wheat.

At Brookings, S. Dak., the extensive plats of wheat and grass gave an opportunity for ready comparison of the attack on different kinds of grains and grasses, but jassids were nowhere plenty. The greatest abundance occurred in fields of native grasses or where a considerable abundance of native grass was present. This included the usual species occurring in prairie grasses and in such abundance that they could be considered of economic importance. The importance of these prairie grasses is recognized, and the writer was told by Prof. James Wilson, director of the station, that they are much used for hay, the method being to cut every two years, and the dried grass of the year previous is said to be equally valuable for forage with the fresh growth. If cut in this manner it can be raked and stacked at once.

At Fargo, N. Dak., jassid injury to wheat, oats, or spring-planted grains was not observable, although a few individuals were to be seen here and there. A few jassids that were afterwards gathered from the examination of a large number of fields in this section indicated that jassid injury to the spring-planted grains is practi-

cally a negligible quantity, and that under the present methods of cultivation in the wheat-growing section of the Red River Valley these insects may be excluded from consideration. In permanent grasslands, however, the situation is quite different, as the author found, especially in fields that have been two or more years in timothy or other grasses, a considerable abundance of leafhoppers, especially of *Deltocephalus inimicus* and *D. configuratus*, with other species in less numbers. One of the most abundant infestations was noted in a field of brome-grass (see Pl. I, fig. 2) which had been planted for about five years and which was used at the time as a pasture. Alfalfa in this section showed little infestation. The prairie grasses showed a considerable abundance of the usual species.

At Ada, Minn., an examination was made of a number of large wheat fields, and these were mostly free from jassids, as were also pasture lands which had recently been planted, but older pasture lands (see Pl. I, fig. 1) included considerable numbers of *Deltocephalus inimicus* and *D. affinis*. The wild grasses of this locality included the same species as were found at Fargo.

At Bismarck, N. Dak., no wheat fields were studied, but a collection of jassids upon the range grasses showed a very abundant occurrence of the species of Deltocephalus, Athysanus, and Lonatura? In less numbers were species of Driatura, Chlorotettix, and Parabolocratus.

At the substation of the North Dakota Experiment Station at Dickinson the author found a considerable number of plats of oats, millet, wheat, alfalfa, etc., and while jassids occurred in small numbers in a number of these plats they were not abundant enough to cause any appreciable injury. In wheat *Cicadula 6-notata* occurred very sparingly, as also in oats and millet. A rather unusual occurrence was that of *Philænus bilineatus* Say in oats. This is an abundant species in the field grasses and probably had migrated from these into the oats field. Upon the wild prairie land (see Pl. III, fig. 2), which includes a mixed assemblage of the buffalo grass, wild-oats grass, etc., there was an abundance of different species of Deltocephalus with some other genera. The range grasses here are of special importance, as they are pastured to a large extent and are also mowed for hay. Wild oats, a most conspicuous element, is said not to be particularly troublesome, and even after the barbs are well formed it is cut and used as hay. In some localities farther east it is looked upon as a distinctly troublesome form.

Near the Mammoth Hot Springs, Yellowstone Park, the writer secured a number of interesting species of Jassidæ upon the annual grasses but a particularly interesting occurrence was noted in a small patch of cultivated grass kept under irrigation (see Pl. III, fig. 3). This patch, located very remotely from any other cultivated grasses and including timothy and clover and some bluegrass, was found

to be fairly swarming with several species of the leafhoppers. The species in greatest abundance was *Deltocephalus affinis* and the next most abundant was probably *Cicadula 6-notata*, then *Deltocephalus debilis* Uhl. with *D. inimicus* very scarce or wanting. How the species ordinarily occurring on cultivated grasses have reached this isolated patch is an interesting question.

Another series of interesting records was made at Bozeman, Mont., on the grounds of the Montana Agricultural College. In plats of wheat, oats, and barley, *Cicadula 6-notata* was found fairly common but not abundant. This species appears to follow these crops entirely across the country throughout the Northern States and also to occur on some of the grasses.

At Pullman, Wash., wheat during this season was very free from jassids although I was informed by Mr. Geo. I. Reeves, of the Bureau of Entomology, of attacks of a species of Dicraneura. Cultivated grasses, however, were considerably infested, timothy by *Deltocephalus inimicus* and *D. affinis*, and a red-top grass by *D. inimicus*, *D. affinis*, *Cicadula 6-notata*, and *Thamnotettix geminatus*. Both clover and alfalfa were infested in considerable abundance by *Athysanus exitiosus*, *Cicadula 6-notata*, and *Deltocephalus inimicus*. Wild grasses of this vicinity show a great variety of leafhoppers, and it would appear that they are quite an important economic problem.

At Kalispell, Mont., the wheat fields appeared to be entirely free from leafhopper injury, a few leafhoppers only being found in volunteer wheat and oats along the roadsides. The usual species, however, were found in considerable abundance in the autumn grasses and a number of species in the wild grasses growing on the unbroken land. One of the most conspicuous species here was *Athysanus sexvittatus* Van D., which was taken especially from a tall red-top grass (Festuca?).

At Williston, N. Dak., on the grounds of the North Dakota Agricultural Experiment Station, the jassids were found on wheat, oats, alfalfa, and clover, but not in any case in such abundance as to be a serious menace to the crops. *Deltocephalus inimicus* and *Cicadula 6-notata* were the most frequently met. The annual grasses showed rather more than the usual abundance and possibly from the lateness of the season or because of the dryness of the grasses in this locality showed more than the usual amount of withering. A field which had been flooded earlier in the season included very few jassids and suggests the possibility that they may have been quite extensively drowned out. Alfalfa of the 1908 planting was free from jassids, while the fields of Bermuda grass of the second year's planting had a much greater abundance than on the first year's plants. In spots here and there were *Deltocephalus inimicus* and *D. nigrifrons*, *Cicadula 6-notata*, and *Draeculacephala mollipes*. Collections were also made at Devil's Lake and Grand Forks, N. Dak., but with little difference in the char-

acter of the collections made and the second examination of the fields at Fargo, N. Dak., July 29, showed about the same condition as had been observed a month earlier with possibly a somewhat greater abundance of the common species in clover and timothy.

Summing up in brief the observations in the northwestern States visited on this trip, it may be stated that leafhoppers were of very infrequent occurrence and practically of no economic significance at this season in the fields of wheat and oats but that the numbers occurring in the range land as well as in pastures and meadows were sufficient to cause a considerable drain upon the crop.

Observations made by the author in Ohio, covering points at Akron, Wooster, Sandusky, Toledo, and Columbus, with other points in the central part of the State, showed only a moderate amount of jassid injury for the season and little indication of attack on fall wheat, although these observations were made too early in the season to determine fully in this regard. At Akron an interesting occurrence of *Deltocephalus apicatus* Osb. was observed, and the food plant for the species there positively determined as *Panicum huachucæ.* This was found occurring on little clumps of its host plant in a meadow, including clover, bluegrass, and timothy. This leafhopper would be found strictly confined to the little patches, not occurring on adjacent grasses or other species. At another point it was taken in large numbers from a small patch where no other grasses grew and individuals of different sizes, representing stages nearly all the way from newly hatched to adult, were found. So abundant was it at this point that about 150 specimens were taken at one sweeping. The host plant (*Danthonia spicata*) for *Deltocephalus melscheimeri* was also found on a woody hillside where the grasses grew practically isolated so that there could be no question as to the host of the leafhopper.

At Urbana, Ill., in meadow land, including timothy, clover, etc., jassids occurred in large numbers, including *Deltocephalus inimicus, D. nigrifrons,* and *D. sylvestris* Osb. and Ball in open fields, and *D. weedii* Van D., *D. sylvestris,* etc., in a woodlot.

In Indiana at Lafayette and vicinity the pasture land examined was found to include the usual forms and in about the ordinary abundance. In a field of soy beans a few specimens of *Empoasca mali* were found, several larvæ and a few adults, showing conclusively that the life history of this species was passed on this crop. Mr. W. J. Phillips informed me that he had found it quite common earlier in the season and noted a distinct injury due to its presence. Most of the other plants in the field, except the variety in which were found specimens, were dead and the leafhoppers had doubtless migrated from them to find fresh food. Plant-lice were also found upon the same plants, but not in numbers to cause much injury. Alfalfa was found to be infested quite freely with *Empoasca mali,* both larvæ and adults, and there were also several other species of leafhoppers, *D. inimicus,* Agallia, etc. An opportunity

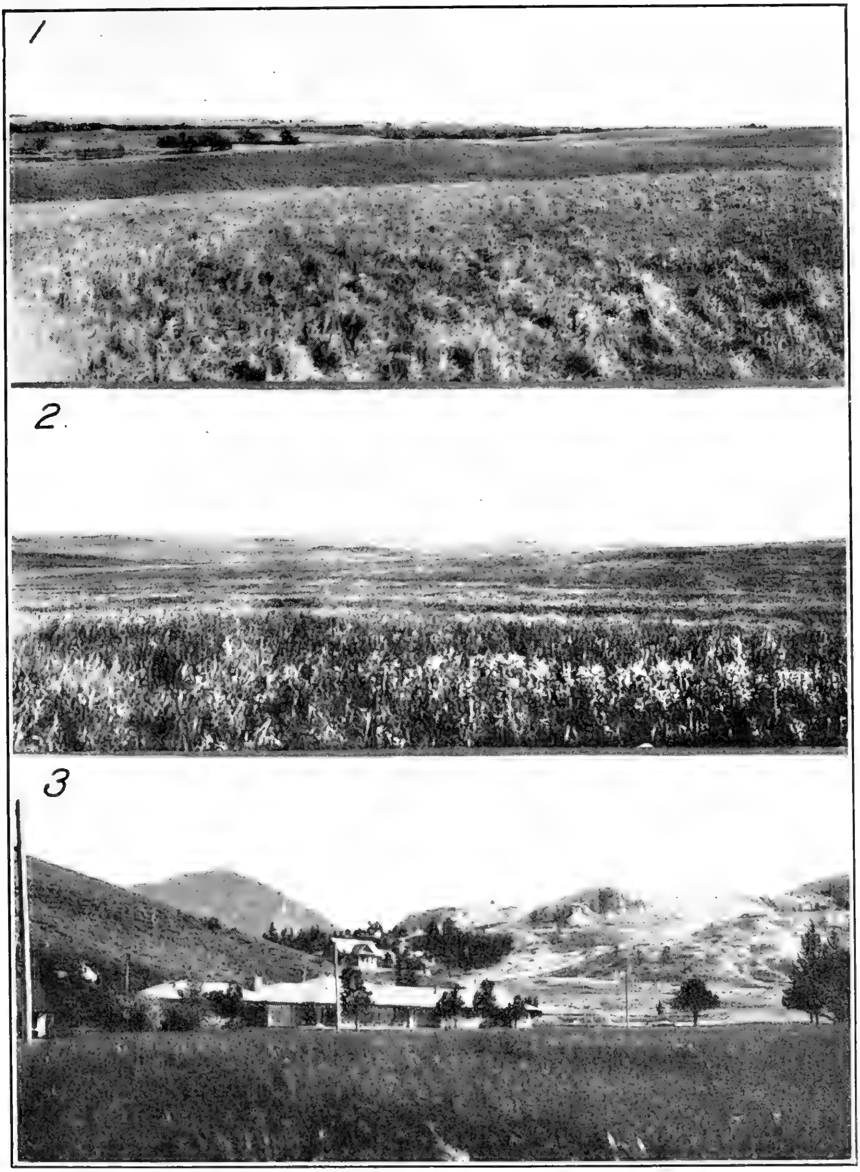

FIG. 1.—WILD GRASSLAND IN CENTRAL KANSAS, INCLUDING GRAMA GRASSES, BUFFALO GRASS, ETC., AND WITH AN ABUNDANT SUPPLY OF LEAFHOPPERS OF THE GENERA DELTOCEPHALUS, ATHYSANELLA, ETC. (ORIGINAL.)

FIG. 2.—WILD GRASSLAND AT DICKINSON, N. DAK., WITH BUFFALO GRASS, GRAMA GRASSES, AND OTHER NATIVE GRASSES AND WITH GREAT ABUNDANCE OF LEAFHOPPERS—DELTOCEPHALUS, ATHYSANUS, ETC. (ORIGINAL.)

FIG. 3.—SMALL PATCH OF CULTIVATED IRRIGATED GRASS IN FRONT OF MAMMOTH HOT SPRINGS HOTEL, YELLOWSTONE NATIONAL PARK, WHICH WAS SWARMING WITH LEAFHOPPERS COMMON TO THE CULTIVATED SPECIES, NOTWITHSTANDING ITS REMOTENESS FROM ANY OTHER CULTIVATED GRASS.

was found to note the migration of leafhoppers into wheat from adjacent grass, as a plat in the experimental grounds where the wheat had only recently come up and which was practically free from any other kind of vegetation was found to be infested with *Deltocephalus inimicus* and *D. nigrifrons.* Collections at Indianapolis gave no particulars different from those which have been observed in other localities.

October 20, at Hamburg, N. Y., the author found leafhoppers quite active, and in a series of narrow strips of wheat alternating with grass it was distinctly noticeable that the leafhoppers had migrated into wheat strips in considerable numbers. In another larger field not far distant the central part of the field appeared to be less infested and it would seem that the distance from adjacent grasses had been a factor in the lesser infestation. This field, however, was too small to give a very good opportunity for noting the distances to which the leafhoppers can easily migrate.

At Valencia, near Pittsburgh, Pa., November 2, the author found *Deltocephalus inimicus* and *D. nigrifrons* with *Phlepsius irroratus, Cicadula 6-notata,* and a species of Balclutha, all in small numbers, probably because of the rain and cold which must have driven them to shelter. Some were found under dead leaves, but others had been exposed, as their movements were sluggish. Most of the leafhoppers seemed to be very well prepared for hibernation, at least were too inactive to furnish much opportunity for examination.

In the vicinity of Harrisburg, Pa., November 4 and 5, several fields were visited, and practically no jassids whatever were found in the fall wheat, a condition which seemed quite puzzling, since the weather was warm enough so that the jassids should have been active. The author learned, however, that the protracted drought had dried up the vegetation in early autumn and inasmuch as the fields examined were mostly upland and as the small amount of grass adjacent had probably been too small to support the jassids earlier in the season there had been no infestation of the wheat. In one field of grass, distant from the wheat fields examined, a small number of *Deltocephalus inimicus, D. nigrifrons,* and *Agallia sanguinolenta* as well as a Liburnia were found. The observations here appeared to be distinctly significant as showing the possibility of preventing injury to fall wheat by the elimination of jassids developing in the adjacent grass fields.

At Reading, Pa., November 6, on a bright, warm day, in fields east of the town, several species of jassids were found, among them *Deltocephalus sayi, D. nigrifrons,* and *Dr. mollipes.* Wheat fields nearby, however, were very clean, free from weeds or grasses, except timothy, which was just appearing above the ground. The jassids were quite few in the wheat, and in the central part of the field, excepting representatives from the adjacent grassland, very few were to be found and none at all at the center of a large field. In none of the

wheat fields examined could jassids be considered of economic importance, none were found under clods, and the scarcity here could probably be attributed to clean culture. In fall wheat at Newark, Del., November 9, very few jassids were to be found.

At College Park, Md., and Arlington, Va., the infestation with jassids was much more extensive than found at any of the other more northern localities and in both of these places was sufficient so that it might occasion noticeable injury. This is particularly true of plats which lie adjacent to strips of grass, such as those along roadways and by the borders of fields. At Arlington, Va., especially (see Pl. II, fig. 2), the conditions indicated the readiness with which the jassids will migrate into fall wheat or other cereal crops from the adjacent grass or from the volunteer wheat of a summers' growth. Individuals were found with the bodies distended as if filled with eggs, but egg laying was not observed, and the dissection of specimens revealed no completely developed eggs.

At Raleigh, N. C., November 15, the author found a particularly interesting location in an oats field which was nearly surrounded by grasslands with strips of grass along roadsides. The oats were very seriously infested with leafhoppers, especially *Deltocephalus nigrifrons*, *Athysanus exitiosus*, and *Dræculacephala reticulata*. *Cicadula 6-notata* was present but not nearly so common as the other species, while only a few specimens of *Phlepsius irroratus* were taken, and *Deltocephalus inimicus* was not observed at all. Many of the plants had leaves that were yellowed or withered and showed spots which had every appearance of being the result of punctures by these jassids. In the grass adjacent to this field all the species occurring in the wheat were found, and in addition *D. flavicosta* Stål, *Xerophlœa viridis* Fab., *Athysanus obtutus*, and *Platymetopius frontalis*. Evidently these latter species are not attracted to oats. It was also noticeable that the oats included only adults, and larvæ were found only in the grasses—another proof of the recent migration from the grasses into the oats, in which particular case it was very clear that treatment of the adjacent grasslands would have lessened if not entirely prevented the infestation of the grain.

At Columbia, S. C., November 16, in wheat fields near the city, an abundance of *Deltocephalus nigrifrons* was found which made up perhaps nine-tenths of the entire number of leafhoppers taken in the fields, while *Cicadula 6-notata* was not common, *Athysanus exitiosus* was quite common, *Dræculacephala mollipes* and *Dr. reticulata* were few, and *Athysanus obtutus* occurred in small numbers. These same species occurred in adjacent grasses, *Deltocephalus nigrifrons* being most abundant, other species in about the same proportion as observed for the wheat, and *Xerophlœa viridis* occurring in small numbers. As compared with conditions at Raleigh, N. C., *Dræculacephala reticulata* seemed considerably less abundant. At Clemson

College, S. C., conditions were much the same as at Columbia, S. C., but quite a noticeable infestation of grasses with *Deltocephalus nigrifrons* as the main element was observed.

At Decatur, Ga., November 19, grass pastures, including mostly Bermuda grass, showed an abundance of *Deltocephalus nigrifrons* with a few *D. obtectus* Osb. and Ball and *Athysanus colonus* Uhl., etc., both larvæ and adults, and a few specimens of *Phlepsius irroratus*. *Dræculacephala mollipes* and *Dr. reticulata* were common, the former in both larval and adult stages, the latter only as adults. The wheat examined was only slightly infested, but being inaccessible, bordered on one side by woods and on the other by a rather barren roadside, small opportunity was present for infestation.

At Knoxville, Tenn., November 22, the weather being bright and warm, jassids were found in abundance and quite active, and the infestation of fall barley especially was quite serious. This had been planted about the middle of September and had made a strong growth and included a large number of jassids, the most abundant species being *Deltocephalus nigrifrons*. Alfalfa fields planted several years were also infested extensively with a number of different species and also red clover two years planted, while the younger fields showed much less injury. It was noticeable that *Dræculacephala reticulata* was not found in any of the collections here, an indication that its present limit of distribution is farther south for this meridian, though farther east and on lower levels it goes much farther north.

OBSERVATIONS DURING THE SEASON OF 1910.

During February, March, and April, 1910, I made a trip through the Southern and southwestern States collecting and studying the local conditions at a number of points.

At Biloxi, Miss., the species occurring in Bermuda grass were studied particularly. Here were found an abundance of the yellow-headed leafhopper *Dræculacephala reticulata*, with other species, and in some places these occurred in Bermuda grass where no other grasses were present. No larvæ of *Dr. reticulata* were found, although larvæ of other species occurred. It was evident therefore, that this species must hibernate in the adult stage.

At Brownsville, Tex., where I spent nearly a week, February 19 to 25, leafhoppers were becoming very active, although the first day or two was cloudy and cold, with occasional drizzling rain. Bermuda grass, oats, and the native wild grasses of the locality were all quite fully infested with different species of leafhoppers and many facts concerning their hibernation and life history were secured as well as the collection of many species not hitherto known from that region. *Dræculacephala sagitiffera* Uhl. was very abundant and apparently replaced *Dr. reticulata*, which I did not collect.

February 26 and 27 were spent at Corpus Christi, Tex., but high winds and cloudy weather interfered somewhat with best results in

collecting. Some especially good records, however, were secured with reference to the food plants and habits of species occurring on the native grasses. (See Pl. IV, fig. 3.)

At San Antonio, Tex., February 28 and March 1, most of the time was spent on the Collins irrigation farms and at the Government experiment station, which furnished an excellent opportunity to compare the conditions in irrigated and nonirrigated areas. (See Pl. IV, fig. 2.) In both places a number of the common species were present, but the abundance differed very decidedly for some of them, showing that they flourished much better in the moist locality.

At El Paso, Tex., the hillsides presented a very barren condition, the grasses being absent or completely dried up and no leafhoppers were found in these localities. In a small irrigated tract near the city several species were fairly swarming and I found here also a species of Stictocephala quite abundant in grass. At Tucson, Ariz., several days were spent, March 6 to 9, where the assistance of the officers of the Desert laboratory and of the Arizona College of Agriculture was obtained. Collections from the cultivated plats of barley, grasses, and alfalfa, as well as from the native desert grasses (see Pl. IV, fig. 1) were made.

At Tempe, Ariz., in the irrigated sections of the Salt River Valley, where many forage crops are grown and where wheat has been cultivated probably for many centuries, particular attention was given to the wheat fields and alfalfa, clover, and grass. A number of the common widely distributed species occurred here and some of these in considerable abundance, although in no case were they so plentiful as to be causing noticeable injury.

At Yuma, Ariz., and Fort Yuma, Cal., considerable numbers of leafhoppers occurred in the irrigated fields of alfalfa, clover, and wheat. On Bermuda grass and in some of the native grasses in nonirrigated fields a number of species were secured evidently belonging to the native fauna.

In the irrigated section of the Imperial Valley collections were made at El Centro and Brawley, Cal., and a variety of crops, including barley, oats, alfalfa, and Bermuda grass, were examined. Very few leafhoppers were found in the oats and barley, but the alfalfa was infested considerably, and the Bermuda grass included several species that were fairly plentiful.

In the vicinity of Ontario, Pomona, and Chino, Cal., there were opportunities to examine fields of alfalfa, oats, barley, and Bermuda and native grasses, but for the most part leafhoppers were very scarce and in some fields only one or a very few specimens could be discovered after dilligent search. On alfalfa the most common species of leafhopper was an Agallia. The native grasses were but slightly infested and very few species were represented.

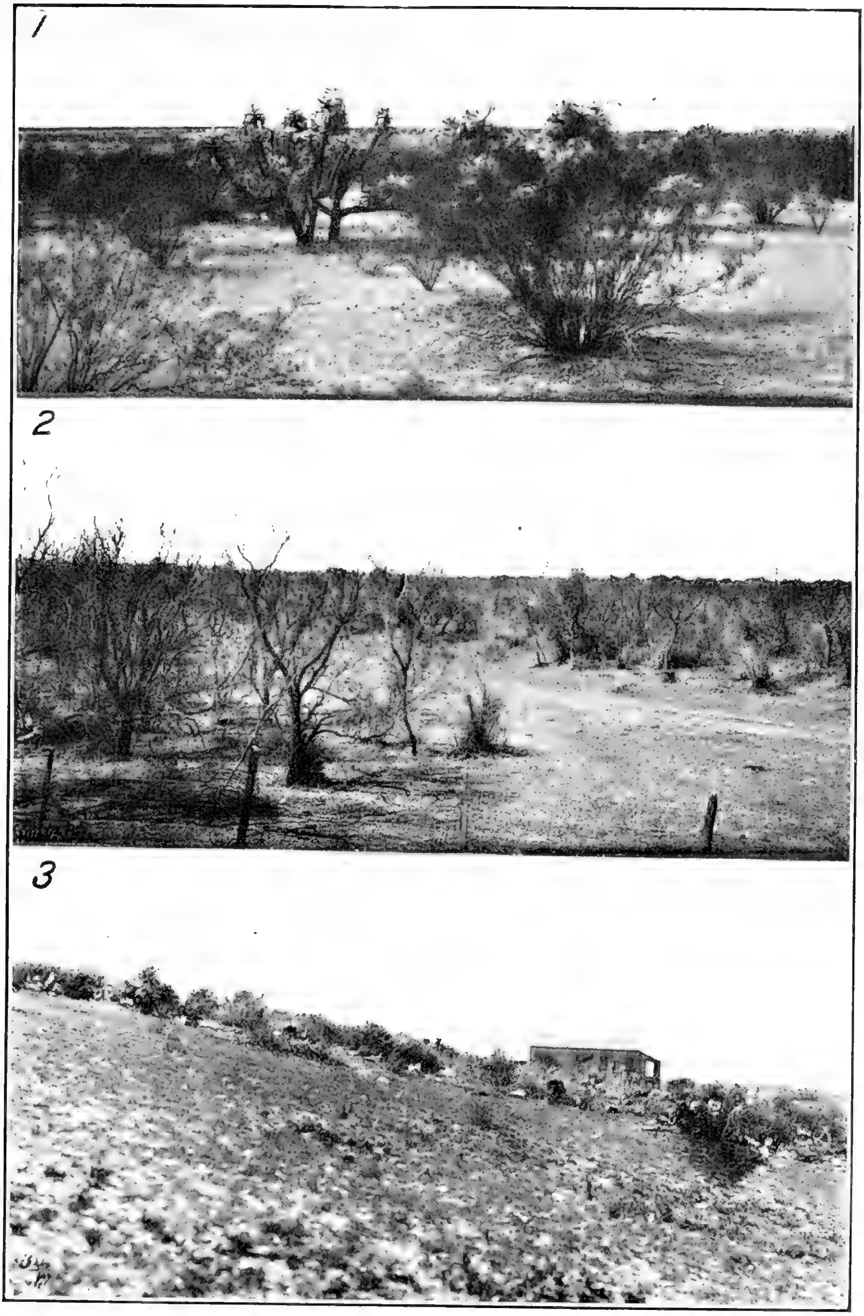

FIG. 1.—DESERT NEAR TUCSON, ARIZ. THE SMALL GRASSES OCCURRING IN SCATTERED CLUMPS AMONG THE DESERT VEGETATION OF CACTUS, CREOSOTE BUSH, ETC., ARE THE HOME OF VARIOUS SPECIES OF LEAFHOPPERS WHICH SURVIVE IN SPITE OF THE EXTREME DRYNESS OF THE HABITAT. (ORIGINAL.)
FIG. 2.—DESERT WEST OF SAN ANTONIO, TEX. HERE THE PLAINS GRASSES THAT ARE COMMON IN THE MESQUITE ARE FAIRLY SWARMING WITH LEAFHOPPERS OF SEVERAL DIFFERENT KINDS, ESPECIALLY THE ATHYSANELLAS. (ORIGINAL.)
FIG. 3.—A BIT OF DESERT-LIKE HILLSIDE NEAR CORPUS CHRISTI, TEX., WITH CACTUS AND MESQUITE AND CLUMPS OF DESERT GRASS WHICH WERE FOUND TO BE ABUNDANTLY INFESTED WITH LEAFHOPPERS. (ORIGINAL.)

In the vicinity of Long Beach, Cal., several of the common species were plentiful in fields of mixed grass and clover and in the native salt grass near sea-level *Lonatura minuta* Van D. occurred in large numbers and in different stages. The barley fields were quite free from leafhoppers, as also the oats fields, although several of the common species were represented in the other fields.

Nearly the same conditions were observed at Sierra Madre, Cal., March 25. The fields of barley, oats, clover, and alfalfa were quite free from leafhoppers, the greatest abundance being found in a field of barley where *Athysanus exitiosus* was fairly common.

At San Diego and La Jolla, Cal., severe rains interfered with good work, but at the latter place a number of species were secured from grasses and oats.

At Whittier, Cal., on March 29, on a warm sunny day, leafhoppers were quite abundant in fields of barley, oats, grass, clover, and alfalfa, and in one field particularly on a southern hillside several species were swarming in great abundance in both larval and adult stages.

At Bakersfield, Cal., August 30, collections were made on wild grasses and other plants and particularly on clover, burr clover, and alfalfa. Several species were abundant. *Athysanus exitiosus* was plentiful, as also several species of Deltocephalus. Three species of Agallia occurred on clover and on a wild species of legume. Other species occurred in less abundance.

At Fresno, Cal., March 31, collections were limited to wild vegetation, but the *Athysanus exitiosus* was found abundant in both larval and adult stages. Deltocephalus of a black variety (*fuscinervosus* Van Duzee) was fairly plentiful and Agallias were swarming in some patches, evidently where the legumes were most plentiful.

At Modesto, Cal., March 31 and April 1, a number of fields of oats, barley, and alfalfa were examined, but the leafhoppers were not abundant. The scarcity of *Athysanus exitiosus* in oats fields would indicate its preference for the native grasses, at least for egg deposition.

Collections in the vicinity of San Francisco, Berkeley, Palo Alto, and Davis, Cal., gave slight results owing to unfavorable weather.

At Logan, Utah, wheat fields were apparently free from leafhoppers but the weather was too cold to favor their activity. Several species, however, were found active among the native grasses and larvæ of Deltocephalus and Cicadula were quite plentiful in some places.

At Grand Junction, Colo., April 17, jassids were active in alfalfa and the wild grasses of the locality.

At Pueblo, Colo., several species were found in bluegrass, the most abundant being *Deltocephalus affinis*. In the wild plains, grasses of several species were common and Athysanella very abundant.

At Colorado Springs, Colo., April 20, on the native grasses leafhoppers were swarming by millions, a number of different species being represented.

The conditions at Fort Collihs, Colo., April 22, were very similar although cold and high wind made the collection somewhat smaller.

In central Kansas, near Delphos, April 24 to 28, jassids occurred in great abundance in the native grasses, but were scarce in the wheat and other cultivated crops.

A short trip in northern Michigan to determine the range of certain species was made in the latter part of June, collections being made at Detroit, Mackinac Island, Sault Sainte Marie, and St. Ignace, most of the time being spent at the "Soo." *Deltocephalus abdominalis* occurred here in large numbers, both larvæ and adults being taken. *D. affinis*, *Cicadula 6-notata*, and other species were abundant.

SYSTEMATIC POSITION OF LEAFHOPPERS.

The insects which are commonly known as leafhoppers are included in the group of bugs, Hemiptera, and in the suborder Homoptera, which includes among other forms the cicadas, plant-lice or aphides, and the scale insects. The name is applied more strictly to the old family Jassidæ, the members of which as a very general thing have the habit of jumping quickly when disturbed, and since their usual habitat is the leaf or stem of plants the term leafhopper is very appropriate. This old family, however, has been subdivided, and there are now recognized three or four families, and the members of all of these may properly be included in a discussion of the leafhoppers in general. The species of economic importance in connection with cereal and forage crops are included in all of them, and there are so many points in which they have similarities of habit, and consequently are open to similar methods of treatment, that it is entirely logical to group them for the purpose of this paper. The most familiar examples of the groups are perhaps the grape leafhoppers, which produce so distinct a whitening or withering of grape leaves in the latter part of summer. The species with which we are more concerned are those which will be seen to rise in great numbers if disturbed from the grass in the pasture or meadow as one walks through the fields.

Aside from the forms included in the Jassidæ proper, the name "leafhopper" has been applied also to some of the "froghoppers" (Cercopidæ), also known as spittle insects, and some of these are so similar in their habits and attacks upon forage crops that mention of a few of them may be necessary. Further, the name "leafhopper" is very generally applied to members of the family Fulgoridæ, especially to the division Delphacinæ. These are minute insects with habits almost identical with those of the jassid leafhoppers infesting grasses, and since they are commonly confused with these, it will be desirable

to discuss some of the more important species in this connection. Outside of the United States some of these are recognized as among the most serious pests, as the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirk.), which has in recent years caused a loss of many millions of dollars to the sugar crop in Hawaii. We have also a species common in the Southern States which attacks corn and which has, at times, been noted as very abundant and destructive. While it may appear unnecessary to discuss the details of classification or of structure in these various groups, the fact that some of the differences presented are such as to have a very important bearing on the distribution or the methods of control makes some such consideration necessary. Moreover, there is a quite important difference in the parasitic enemies which may be found to occur on the different forms, and this alone would be ground for a careful designation between forms which are essentially different although bearing the same common name.

EXPLANATION OF TERMS USED.

While it is possible in the description of the different insects treated here to use a number of common terms, such as head, wings, legs, abdomen, eyes, face, etc., and the descriptions are therefore intelligible to anyone so far as these go, it is necessary for the sake of precision in some instances to use terms which are less generally known, or at least not definitely applied. An explanation, therefore, of a few terms which are really necessary for the accurate description of the different forms mentioned will be given in order to make the paper of service to those who have no technical knowledge of entomology, but whose acquaintance with ordinary English should enable them to place the particular insects which are under discussion.

The term *vertex* is used for the upper surface of the head between the eyes and extending to the front border, which may merge gradually into the front or the face. The *frons*, or *front*, is the part of the face lying between the sutures and extending down nearly to the lower border. At the sides of this are portions next the eyes, which are termed the cheek and below the front a part called *clypeus*, at the sides of which are the *loræ*. The central part of the body which bears the wings and legs is termed the thorax, and the upper portion of the first segment is known as the *pronotum*. The front wings are termed *elytra* and are usually thicker and stronger than the hind pair, which are concealed beneath the front ones when at rest. The hinder distinctly segmented part of the body or *abdomen* may be entirely hidden above by the wings, but in short-winged forms is more or less exposed. The parts of greatest importance on the abdomen for purposes of description are the terminal segments, including the genitalia. In the female the last ventral segment is frequently of a particular shape or structure for different species, and in many groups is of the greatest service for description. It is followed by the sheaths of the

ovipositor, this latter being a narrow sawlike pair of blades extending to the tip, sometimes considerably beyond the tip of the sheaths. The males have for the terminal segment beneath a modified segment, called the *valve*, which is followed by two movable pieces called *plates*. Above these, forming the sides of the last segment, are the *pygofers*. A ready understanding of these various parts will be helped by a study of the accompanying figure 1, in which they are located

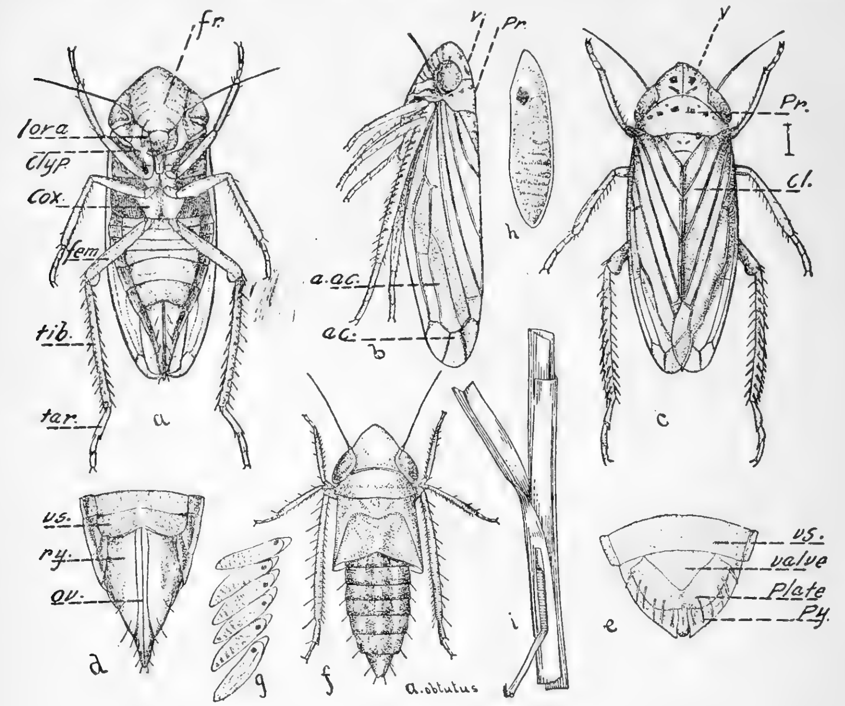

FIG. 1.—Explanation of terms from drawing of *Athysanus obtutus*: *a*, Female from beneath; *b*, from side; *c*, from above; *d*, female genitalia; *e*, male genitalia; *f*, larva or nymph; *g*, eggs, showing developing larvæ; *h*, egg, enlarged; *i*, eggs in position beneath sheath of grass stem. Structural details: *ac*, Apical cells; *aac*, anteapical cells; *cl*, clavus; *clyp*, clypeus; *cox*, coxa; *fr*, front; *fem*. femur; *lora*, lora; *ov*, ovipositor; *plate*, plate; *pr*, prothorax; *py* (♂), *ry* (♀), pygofer; *tar*, tarsus; *tib*, tibia; *v*, vertex; *vs*, terminal ventral segment; *valve*, valve. All enlarged. (After Osborn and Ball.)

and named. For the different stages of insects the usual terms egg, larva, or nymph, pupa, and adult are used, as these are sufficiently definite in indicating the steps of development from the egg to the mature form.

THE MORE IMPORTANT SPECIES AFFECTING CULTIVATED CROPS.

THE YELLOW-HEADED LEAFHOPPER.

(*Dræculacephala reticulata* Sign.)

The yellow-headed leafhopper (*Dræculacephala reticulata* Sign.), an extremely abundant species in the southern United States, has been noticed a number of times as destructive in wheat or oats, but has never received any full discussion, and we are still ignorant as to the details of its life history. It was described by Signoret as

Tettigonia reticulata in 1854 from specimens derived from Cuba and without any statement concerning its importance. Later, in 1880, it was redescribed by Prof. C. V. Riley and renamed *Diedrocephala flaviceps*, and in connection with the description appears the note, "Numerous specimens injuring wheat and oats in Texas." In Insect Life there is a record of its destructive abundance in South Carolina, and the records of the Bureau of Entomology include a number of instances of its occurrence in wheat and other crops.

DISTRIBUTION.

In Van Duzee's catalogue the distribution of the species is given as from Carolina to Texas. Ball gives a further statement of dis-

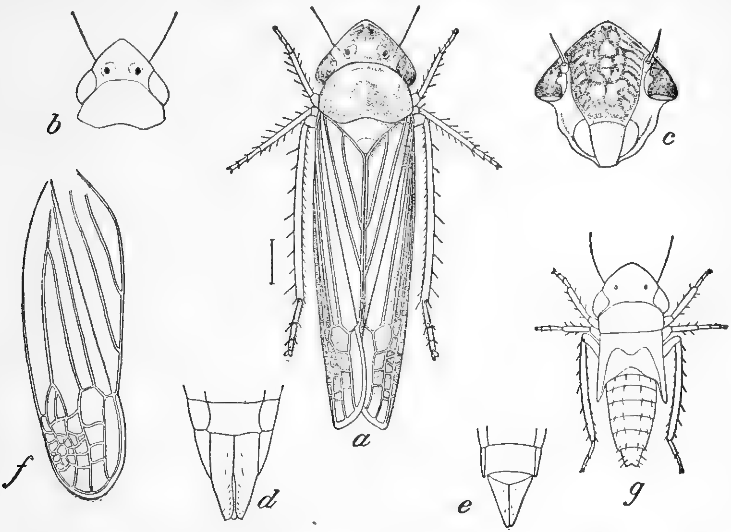

FIG. 2.—The yellow-headed leafhopper (*Dræculacephala reticulata*): *a*, Adult; *b*, vertex; *c*, front; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, supposed nymph from North Carolina. All enlarged. (Original.)

tribution covering South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, South Carolina, and Mexico, which, with the original description from Cuba, gives it a considerable range. Records in the Bureau of Entomology add Charlottesville, Va., as a more northern point, and during the past season it has been found in large numbers at Raleigh, N. C., Clemson College, S. C., and Decatur, Ga. There is one record of its occurrence in Lincoln, Nebr., which is the most northerly point from which we have found any indication of its presence, and so remote from other recorded localities that it may be based on an exceptional occurrence. If common there, it should also be found at intermediate points between this and Texas, but careful collecting has failed to discover it in Kansas. There is also a record for Fulton, Ky. I took it in Mississippi and also in Tucson, Ariz., in 1910. Prof. Ball has a record for Salina, Cal., and I took a similar form at Yuma, Ariz., in wild grass, but

this differs in having a triangular spot on the vertex. I did not find it at Knoxville, Tenn., although it certainly should have been there at the time I was searching for it (November 22, 1909), as other leafhoppers were quite active at the time. It appears, therefore, that there is a northern limit for the species, and this limit is not determined by any limitation of food plants, since the species occurs readily on various plants, a number of which are common at points farther north.

FOOD PLANTS.

The food plants of the species have generally been stated as wheat or oats, but since these records usually come from cases of excessive abundance during autumn it is very evident that they are based on migrations from adjacent fields. This was clearly determined during the present autumn by the finding of adults and larvæ in grassland adjacent to wheat fields at Raleigh, N. C., and at Columbia and Clemson College, S. C. At Raleigh it occurred in strips of bluegrass with other grasses; at Columbia and Clemson College particularly in Bermuda grass; and it was also found in Bermuda grass in fair abundance at Decatur, Ga. In Mississippi, Texas, Arizona, and California it was found most constantly in Bermuda grass and this is accredited as being one of its favorite hosts, but the records are too meager to permit the assertion that its range is coextensive with this plant. While observations are wanting, it may be very safely assumed that the eggs are deposited in some of these grasses of general distribution, that the larvæ develop upon these during early summer months, and that only after maturity do they spread from these to the wheat and oats.

DESCRIPTION.

This species is one which is very easily recognized, since it differs definitely from the other leafhoppers with which it is ordinarily associated. The structural features are shown in figure 2. The head is of a rather bright yellow or orange-yellow color, with two light spots on the vertex, including ocelli, and the forewings are light green. Beneath, including the legs, it is of a pale yellow color, the borders of the abdomen being slightly reddish.

A nymph which was referred to this species was found associated with adults at Raleigh, N. C., in the autumn of 1909. This was grayish, with orange patches on the sides of pronotum, and the same form associated with adults of *reticulata* has been sent to me from Dallas, Tex., so I feel confident that this is the nymphal form. A quite differently appearing nymph with more pointed head and a dark line along the middle line has been referred to this species by Prof. E. D. Ball, based on California specimens, but must, I think, be different or indicate a separation of the California form.

PROBABLY AN INTRODUCED SPECIES.

With the evidence at hand it appears quite certain that this species was introduced into the United States from a more southerly habitat. While the species might possibly have been overlooked by early collectors, it is too conspicuous a species where it occurs for this to be probable. Moreover the records would seem to indicate an advance toward the north since its first appearance in our Southern States. Its original description from Cuba, 1854, precedes any record here, while the early records refer to such southern localities as Texas and South Carolina, a distribution still holding in 1894, when Van Duzee's catalogue was published. In 1900, as recorded

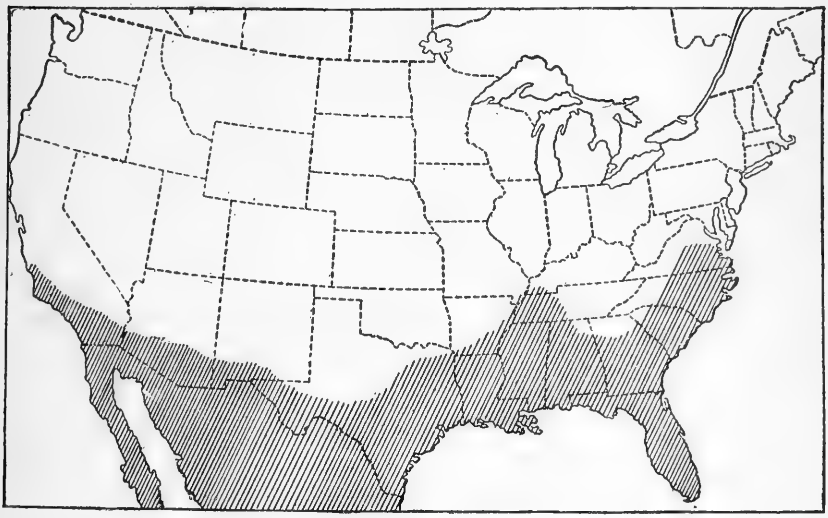

FIG. 3.—Map showing distribution of *Draeculacephala reticulata* in the United States. (Original.)

by Prof. E. D. Ball after he had made an exhaustive examination of records and specimens, the species had not spread north of the Gulf States and South Carolina. Now, however, it is found north, in the Atlantic region to middle Virginia (1906) and in the Mississippi Valley to southern Kentucky (Fulton in 1905). (See fig. 3.) That it is restricted climatically is evidenced by the slow progress made and its limitation to the warmer zone, the line of its northward distribution agreeing very closely with that of the cattle tick.

TREATMENT.

While additional knowledge concerning the place of egg deposition and development of nymphs and especially as to the number of generations during the year may furnish a better basis for the recommendation of measures for control, we may very safely conclude that the depredations on wheat and oats could be very materially lessened

by attention to the various grasses growing in the waste land adjacent to cultivated fields. Mowing and even burning over all such areas should very greatly reduce their numbers and if this is attended to before or soon after the appearance of wheat above the ground the attacks on this crop should be largely prevented.

DRÆCULACEPHALA MOLLIPES Say.

The species *Dræculacephala mollipes* (fig. 4) was described by Say in 1831 among the early descriptions of American insects and has been a very commonly observed species ever since. Nevertheless it seems to have received much less notice from the economic standpoint than it merits. It was mentioned by Dr. Fitch in his list of

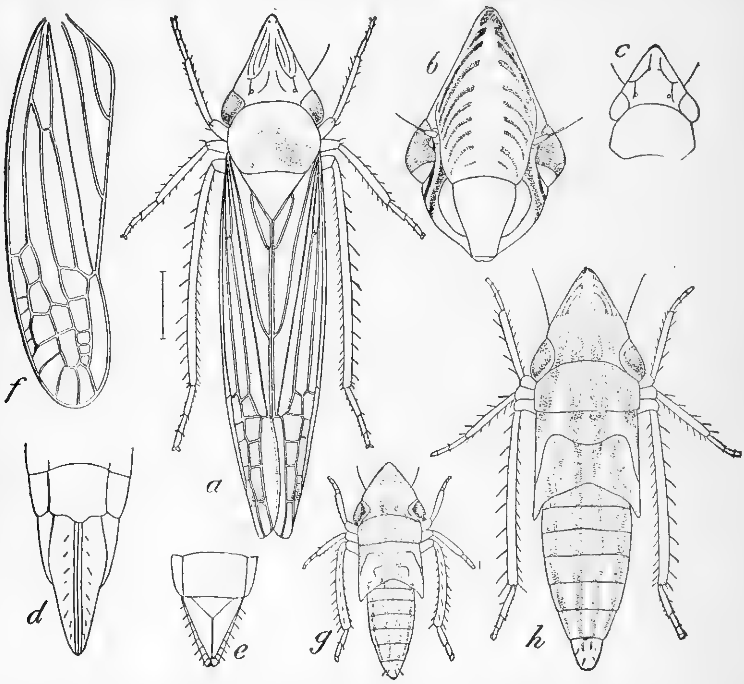

FIG. 4.—*Dræculacephala mollipes:* a, Adult from above; b, face; c, vertex and pronotum; d, female genitalia; e, male genitalia; f, wing; g, h, nymphs. All enlarged. (Original.)

insects in 1851, but without economic discussion; in 1884 Uhler gave a description in the Standard Natural History, saying that "the salt marshes of the Atlantic States furnish places of shelter for it where it may be found on weedy grasses in all stages from June to October." In 1890 Prof. H. Garman, in the Second Annual Report of the Kentucky Agricultural Experiment Station, describes it as a corn pest and speaks of it as abundant in several stages of growth on corn on low ground, generally concealed in the hollow formed by the partly unfolded blades. It evidently occurred in different stages, as he says that the recently matured specimens predominated

there, there being about half as many males and about the same number of young. This occurred at about the time the corn was about 2 feet in height (probably midsummer), as many as 20 leafhoppers being observed on a single plant in some of the fields. The area affected was not large, and the insects were not often found on corn on high ground. He also mentions that the species was affected by an epidemic disease, due to an insect fungus, *Empusa grylli.* In this connection it may be mentioned that Prof. Webster has a record of the occurrence of this fungus on this same species many years ago, the fungus being identified by Prof. Roland Thaxter at Harvard University. The writer called attention to the abundance of this species and gave a brief description of its economic status in Bulletin No. 22 of the Division of Entomology, U. S. Department of Agriculture, and in later years, 1891 and 1892, added some facts concerning its life history. In 1897 he published a brief summary of observations made by Mr. J. A. Rolfs on the method of egg deposition and the limits of broods.

DISTRIBUTION AND FOOD PLANTS.

This is one of the most widely distributed American species of leafhoppers, occurring throughout practically all of North America south of the strictly boreal portions of Canada. During the summers of 1909 and 1910 it was collected at every locality visited and usually in considerable numbers. A detailed record of the localities will include a list of practically every town where any collection of jassids has been made. Its range in food plants is also considerable, although it has apparently a distinct preference for certain grasses growing in the moister ground. It has been taken upon wheat, oats, rye, and barley, and the list of grasses affected includes many species. Bluegrass is apparently a less favored food plant, although it is often found in bluegrass fields, especially where other grasses are present.

DESCRIPTION.

The adult insect is of a bright grass-green color, quite slender in form, and when resting upon a blade of gress is very inconspicuous; in fact, can scarcely be seen unless it jumps or takes wing. The head is very sharply pointed, of a yellowish-green color, and is marked by several very delicate oblique lines. Beneath it is nearly black, the legs greenish, the wings a nearly transparent milky white; the length is about one-third of an inch for the female and about one-fourth of an inch for the male.

LIFE HISTORY.

It is rather curious, considering the great abundance and wide distribution of the species, that a full description of the nymphal stages has

not been published. This may be due in part to the very great abundance of the species and partly, perhaps, because the nymphs, while presenting evident characters, are not particularly striking in appearance; and partly, perhaps, it is due to general neglect of life-history studies for this group of insects. Egg deposition occurs in autumn and is at this time mainly confined to large-stemmed grasses occurring in the low ground or thoroughly moist locations, a selection which may be due to the more succulent character of the plant at this time or to a choice for the larger stems. The deposition in midsummer appears to be less restricted, and apparently the insects occur in the borders of the leaves as well as between the leaf sheath and stem. The series of eggs collected by Mr. R. A. Vickery, at Salisbury, N. C., which quite certainly belong to this species, were placed beneath the epidermis along the margin of the leaf, the inner end of the egg extending to the midrib. Owing to parasitism these eggs did not hatch, and the determination of the species is not absolute. Mr. Vickery, however, secured similar egg deposition in a leaf of corn when the insect was confined with this plant.

The newly hatched nymphs have not been observed, but nymphs of later stages have the characteristic shape of the adult, the head is sharply pointed, a little less so in the early stages, and becoming a little more acute with each of the molts. They are of a light-green or yellowish color, with four dorsal parallel stripes running very nearly from the front of the head to the end of the body. These stripes diminish gradually toward the end of the body, the two outer ones disappearing with the middle of the abdomen, while the two central ones continue to the end. The different molts agree quite closely in appearance, except in the development of the wing-pads. These in the last nymphal stages form the angles extending to the backs of the second abdominal segments.

There are clearly two distinct generations annually and a somewhat irregular occurrence of different stages during the autumn and winter owing to the survival of nymphs and adults. Hibernation seems to occur in all stages from the egg to the adult, although the great majority must pass the winter in the egg stage. Eggs hatching in the spring give rise to nymphs which reach maturity by the latter part of June, and these adults survive until about the 20th of August. The second generation of nymphs begins to appear about the second week in August and continues through September, appearing in October and November, although some individuals may be found as adult by the middle of September and others remain as nymphs until winter. These dates will vary somewhat with latitudes, and possibly a greater number of generations may be found in the southern localities, but no positive observations are on record for such regions.

MIGRATION.

Aside from the local migration which works in passing from field to field and the selection of attractive areas, the insect shows at times a distinct habit of migration at night. A number of instances are known where immense numbers have collected around electric lights, and this would seem to be associated with some general movement which brought them, perhaps the wind, as otherwise we can hardly account for the movement from their sheltered locations near the ground. Such migrations are observed during midsummer but, so far as I know, no instances of the migrations in late autumn have been observed.

REMEDIES.

Available remedies for this species are suggested in its habit of selecting the coarser kinds of grass for egg deposition in autumn, as it is quite possible to cut or burn such grass, and in this way the number of eggs that survive will be greatly lessened. The insect jumps very readily and may be captured in the hopperdozer quite successfully. It would also be open to treatment with the spraying machine when it occurs in fields which could be run over by such apparatus.

That the species is kept in check by parasites is evidenced by the fact that eggs are parasitized by one of the minute forms, probably Trichogramma, the species undetermined.

The occurrence of the fungus mentioned above may also be considered a distinct factor in the control of this species, although we can not suggest any practicable means of extending its operations. Doubtless the activity of predaceous species of insects and spiders plays a very considerable part in keeping the numbers down, and birds should be expected to take a larger proportion of these than of the smaller species.

DRÆCULACEPHALA NOVEBORACENSIS FITCH.

Dræculacephala noveboracensis Fitch is considerably larger than *Dr. mollipes,* and a little lighter in color, the shape of the head is different, being shorter and blunter, and there are two very distinctly marked dots at the tip. In its distribution it covers the larger part of the northern United States, from Vermont to Vancouver's Island, and south in the plateau region to Colorado, but its food plants are restricted to the coarse grass of low ground, and the common slough grass is apparently one of its favorite host plants. Adults are commonly taken during the latter part of June, through July, and from the middle of August until October, so we may safely assume that there are two generations annually and a life cycle corresponding closely to that of *Dr. mollipes.*

The nymphal forms have not been heretofore described, but were observed at Seattle in 1909, occurring on the coarse grasses upon which the adults were found. They are light green with pale wing-pads. The head is only bluntly pointed. The economic importance depends entirely upon whether the coarse grasses upon which it feeds have any economic importance. In some places these are used for hay or for covering to haystacks, while in some parts of the Northwest they are being used quite extensively in the manufacture of mats and various kinds of furniture. In any case it would be a more difficult species to control than *mollipes* on account of the rank growth of the grasses upon which it occurs. The main opportunity for attack would seem to lie in a cutting of the grass in autumn after egg deposition, which would serve to destroy the eggs or remove them from the locality where they could be of injury.

Diedrocephala coccinea Forst.

Diedrocephala coccinea Forst. is a bright colored species, one of the handsomest of all jassids, about the size of *Dræculacephala mollipes* but differing in the shape of the head, which is rounded in front. The elytra are marked with brilliant blue and red stripes. The nymphs are yellow with dark wing-pads.

There are two generations annually, and nymphs of the first generation occur during May and June, and adults may be found about the middle of June until the latter part of July and for the autumn generation during September and October. The nymphs, therefore, must develop during the periods from the latter part of June until late August. Apparently the winter is passed in the egg form, and nymphs should occur in the spring from the hatching of eggs earlier in the season. The species is much more common in woody localities and usually is to be swept from the undergrowth of grass and weeds. It occurs, however, in localities where grass is a large admixture of the vegetation, and it seems quite certain that the grasses constitute a part of its food supply.

The Bog Leafhopper.

(*Helochara communis* Fitch.)

The bog leafhopper (*Helochara communis* Fitch) is an extremely abundant species throughout the larger part of the country, and may be found in practically every locality in the United States where suitable food plants occur.

It is a small, dark-green species, about one-fourth to one-third of an inch long, the head and prothorax longer than the rest of the

body, and the surface, especially of the head and pronotum, distinctly pitted. It appears somewhat like *Dræculacephala mollipes*, but the head is much less pointed and the color is a darker green. (See fig. 5.)

The life cycle has not been worked out in detail, but nymphs evidently belonging to this species may be found during midsummer in the low, swampy grasses where the species is evidently abundant. The food plants consist of swamp grasses, and the insect is found in greatest abundance upon the small, fine grasses of the genus Juncus, but so far as known it is not restricted to any particular species. It is found only in rather moist locations, never on the high, dry ground. It is therefore of much less economic importance than some of the

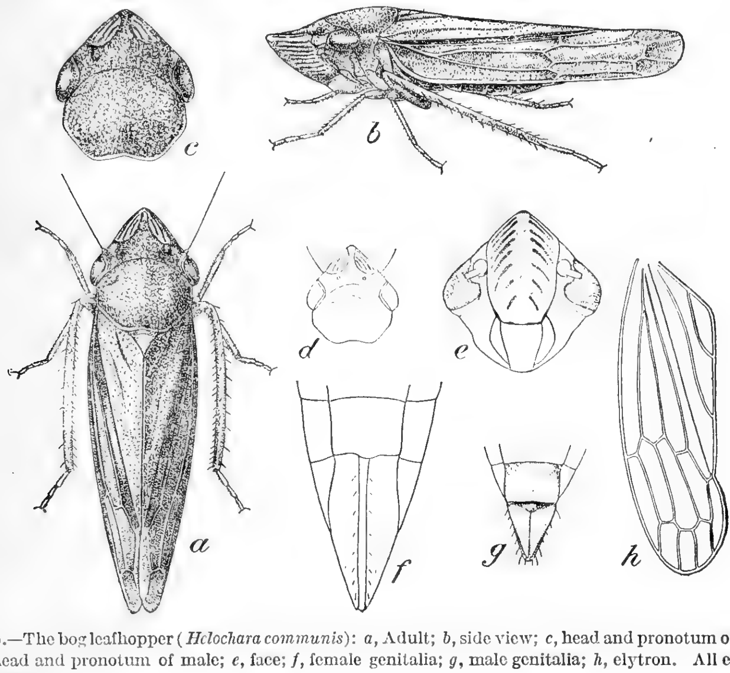

FIG. 5.—The bog leafhopper (*Helochara communis*): *a*, Adult; *b*, side view; *c*, head and pronotum of female; *d*, head and pronotum of male; *e*, face; *f*, female genitalia; *g*, male genitalia; *h*, elytron. All enlarged. (Original.)

other species. So far as these lowland grasses have a forage value it is of course to be counted, and since it occurs sometimes in enormous swarms it may cause a considerable reduction in growth. The actual effect of its presence is seldom observed, as the grasses on account of their abundant moisture keep their color in spite of the drain caused by the insects. The species is one which could not be easily controlled, since the methods of treatment available for pastures and meadows are not so applicable in the low ground where these forms occur. Probably the spraying methods would be most effective, as these could be used where the hopperdozer would not work to advantage.

Gypona octolineata Say.

Gypona octolineata Say is a rather general feeder but it occurs so commonly in grasses and in grain fields that it must be reckoned as one of the grass-feeding species. It is a large insect, the size varying from a third of an inch to one-half inch in length and the color is light yellowish green with a series of dark yellow or orange lines running lengthwise from the head and thorax. Nymphs, which are commonly met with in fields, are very broad and flattened, much flatter than even the adult, which they resemble, in fact, so that they may be easily recognized. The head is narrowed in front of the eyes, the front portion of the head being extremely thin, and the antennæ are quite thin.

The general color is green and the surface of the body is covered with a rather dense fine hair, the fully developed nymphs of the last nymphal stage being broader and shorter and of a darker green than the other stages, and there being two brown spots on the inner angle of the wing-pads. There are two generations annually, the life cycle in general consisting of the appearance of the nymphs by the middle of June and the completion of these nymphal stages about the middle of July. The adults of the midsummer generation appear from about the 1st of July until about the middle of August and the second nymphal generation from the latter part of August through September. The adults of the autumn generation appear in September and remain until the middle or latter part of October. Presumably eggs are deposited in autumn, as no adults have been observed in early spring. The species is extremely widely distributed and has been given a considerable number of different names, based either on geographic distribution or upon the variations which may occur in some locality. A quite prominent form has a distinctly scarlet color in autumn, but otherwise seems not to differ from the ordinary form. Its food plants are so varied that it is difficult to suggest any ways by which it may be controlled, based on food plants or locations of egg deposition, and it seems necessary to leave it to the control of natural enemies which, on the whole, appear to keep it fairly within bounds.

Gypona bimaculata Spang.

Gypona bimaculata Spang. is a very large leafhopper, the largest, in fact, of any which is known to attack grains and grasses in the United States, and it is a species quite generally distributed throughout the northern portion of the country, occurring from New York and Pennsylvania westward through Ohio, Indiana, Illinois, Minnesota, and Iowa to the west. It was described as *bipunctulata* in 1887 by Woodworth, but no account which considered it as an economic

species appeared before a statement of its life history in the Proceedings of the Iowa Academy of Science in 1897. The females are a light, bright green, very robust and thick bodied, the thorax very broadly covered, the ocelli small. There is a distinct black dot on each side of the pronotum about halfway from the middle to the margin; also a minute dot near the base of each wing cover, just back of the angle of the pronotum. It has been known to occur on a variety of grasses, more especially the lower growing, coarser grasses of swampy or boggy places. Whether it has a restricted habit for the deposition of eggs or whether the nymphs are confined to any particular grass is not determined. There is only one generation, and the adults appear about the middle of July and remain until the latter part of September. Full-grown nymphs have been taken in Iowa from prairie grasses in early July. Evidently the eggs are deposited in autumn and survive the winter, presumably upon some of the coarse grasses on low ground.

TETTIGONIA BIFIDA Say.

The species *Tettigonia bifida* Say has not figured as an economic insect, but on account of its wide distribution and its abundant occurrence, in many instances, it seems worthy of more recognition than has been given to it. Its range of food plants is limited, the insect being found almost exclusively in or near wooded pastures, where it occurs especially in bluegrass and may be found as adult during a number of weeks in late summer. Its general life history was worked out in connection with the study of grass-feeding leafhoppers in Iowa some years ago, but aside from that no description of habits or life history has been given.

The adult insect is about one-fourth of an inch long and of a deep greenish color and with circular alternate bands of black and white on the head and pronotum, and the forewings have seven distinct stripes, the dark one being forked near the middle. The adults are noticed early in July and become distinctly abundant by the middle and latter part of the month, after which they diminish in numbers and disappear early in autumn. Egg deposition occurs evidently during July or August and nymphs appear during these months. The nymphs when first observed were about half the length of the adults and fully as broad, with the surface of a powdery-white appearance. The head is large, broad, and deep, almost round in front. The eyes are dark, the wing-pads broad and short. The abdomen is somewhat keeled along the dorsal central line. These nymphs are distinctly different from those of any other members of the genus and may be easily recognized. While the species is not anything like so abundant as some of the other forms, it has been collected in rank bluegrass in such numbers as to give an estimate of 50,000 per acre.

Hecalus lineatus Uhl.

Glossocratus lineatus Uhler, Bul. U. S. Geol. and Geog. Surv., vol. 3, p. 464, 1877 (♀).

Glossocratus fenestratus Uhler, Bul. U. S. Geol. and Geog. Surv., vol. 3, p. 464, 1874.

Hecalus lineatus Uhler, Osborn and Ball, Proc. Iowa Acad. Sci., vol. 4, p. 188 (♀) (♂).

Hecalus lineatus Uhl. is one of the largest of the grass-feeding species. (See fig. 6.) The female measures 12 mm. to the tip of the exserted, attenuate ovipositor. The head is 2.5 mm. long by 2 mm. broad, slightly narrowed in front of the eyes, widening immediately to a spoon-shaped tip, which is thin and slightly reflexed. The body color is bright green, with four equidistant parallel lines extending

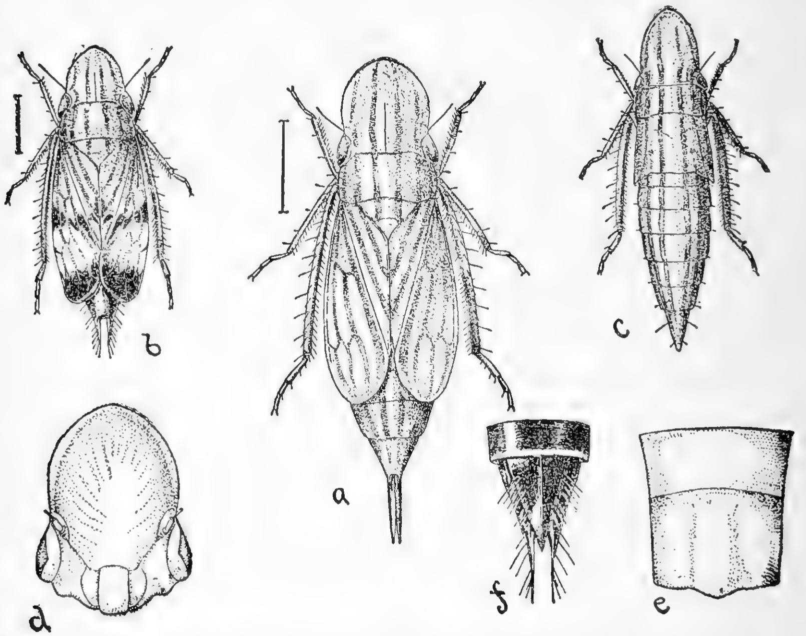

Fig. 6.—*Hecalus lineatus*: *a*, Female; *b*, male; *c*, mature nymph; *d*, face; *e*, last ventral segment of female; *f*, male genitalia All enlarged. (After Osborn and Ball.)

over the head, thorax, and scutellum; the nerves of the elytra and ovipositor are orange-red.

The males are quite different from the females in appearance, and were described by Prof. Uhler as *Glossocratus fenestratus,* and were long regarded as a distinct species. They are much smaller, measuring scarcely 8 mm. to the tip of the style-like pygofers. The head, thorax, and basal part of the elytra are marked as in the female but the ground color approaches orange. The apical half of the elytra and the abdomen are quite different. There is a narrow black band just back of the middle of the elytra and a broader terminal one;

between these is a hyaline area with a small, curved, dark spur extending in on the center of the outer margin. The abdomen is annulated with black, and the terminal segment, valve, and attenuate plates are black.

The nymphs are narrow, elongate, closely resembling the female in color and in the stripes which extend along the abdomen.

The nymphs were found at Ames, Iowa, on an isolated patch of slough grass (*Spartina cynosuroides*) early in August. They were then nearly full grown.

At Ames, Iowa, the adults were taken in coitu in the middle of August, and from then on through September were found in some numbers on the limited patch where their food plant occurred.

It is highly probable that the eggs from the autumn generation are deposited in the stems of slough grass before the middle of September, in which case the ordinary time of mowing would be an effectual remedy, and would account for the rarity of the species in cultivated areas, or in sections annually overrun by prairie fires.

The species has been collected at many different places in the country but never in large numbers. Its paucity in collections, however, is not to be considered as proving its rarity, as it is not so easily captured as many of the jassids unless its particular habitat is known.

It had been reported from Kansas and New Jersey, including only a few specimens in all, and there was a specimen in the Van Duzee collection from New York, and one specimen had been taken at Ames and another at Batavia, Iowa, up to the time that its life history was studied at Ames.

At Ames, Iowa, it was found in considerable numbers and observations recorded in the Proceedings of the Iowa Academy of Sciences, volume 4, 1897. Since then it has been recorded for a number of localities and during the summer of 1909 I collected it in South Dakota at Brookings in June, at Ada, Minn., in early July, and at Devils Lake, N. Dak., late in July. In all probability it may be found over much if not all of the territory covered by the coarse slough grass (*Spartina cynosuroides*), which is the only plant on which larvæ have been recorded and which may be the only host plant for the species.

The Shovel-nosed Leafhopper.

(*Dorycephalus platyrhynchus* Osb.)

The shovel-nosed leafhopper (*Dorycephalus platyrhynchus* Osb.) is one of the most remarkable of the grass-feeding jassids (see fig. 7), being peculiar both in its appearance and habits. It is very seldom seen, since it closely resembles the plants on which it occurs and moreover does not jump readily as is the case with most of the leafhoppers. The records made in Iowa, where its life history was worked out, are

the principal ones so far appearing, but it is listed also from Nebraska and a specimen from Wellington, Kans., in the bureau collection evidently belongs here.

"It is single brooded, the adult appearing about the middle of May and continuing in decreasing numbers until the end of July. During the last week in May and the first week in June the eggs are deposited; the female selects a spot about 2 inches above the base of the first or second leaf from the bottom; having selected the spot apparently with much care, she takes her position head upwards, legs placed

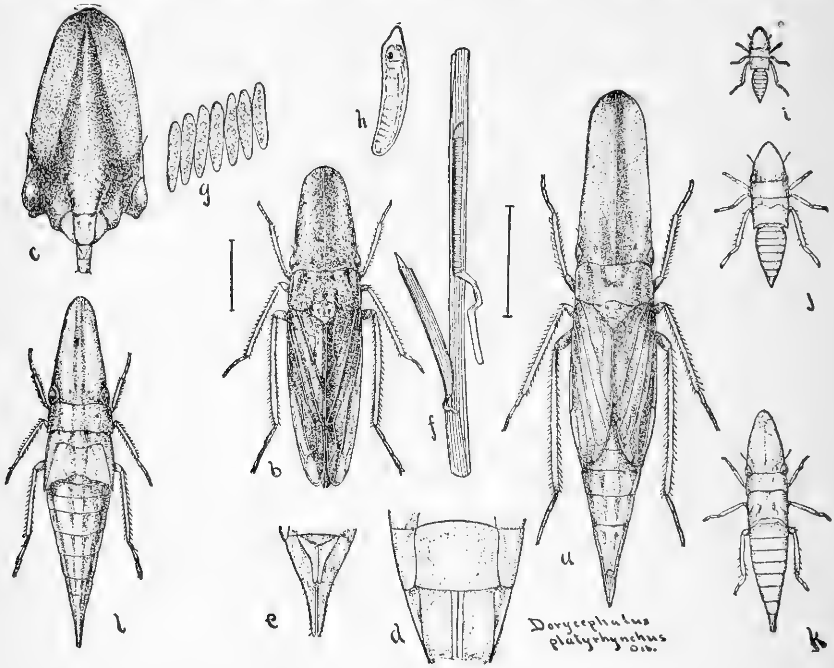

FIG. 7.—The shovel-nosed leafhopper (*Dorycephalus platyrhynchus*): *a*, Female; *b*, male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, eggs in grass stem; *g*, eggs; *h*, egg, more enlarged and showing developing nymph; *i*, *j*, *k*, *l*, different stages of growth of nymph. All enlarged. (After Osborn and Ball.)

close together and tarsi clasping the stem; then, raising the body the length of her legs and curving the abdomen upward, she unsheathes the ovipositor from the pygofers and brings its tip down against the grass stalk, pointing backward slightly from the perpendicular; she then moves slowly around the stem, keeping the body parallel with it and the guides pressed firmly against it until they catch under the edge of the encircling leaf sheath; having done this they are gradually forced under the sheath, usually extending almost half way round the stem. As they are gradually forced in, the abdomen straightens and then hollows until, when the ovipositor is fully inserted, the abdomen is curved down, and the pygofers are pointed upward and backward at more than a right angle with the guides. Having reached this position she works slowly backwards, opening the sheath

downward with a peculiar sawing motion alternating with a slight pause for the deposition of an egg.

"The eggs are one and one-half millimeters by one-third millimeter, cylindrical, gradually tapering from a point near the head back to an obtusely rounded tip; the anterior end is cut off obliquely from one side and rounded from the other, coming to an obtuse point. They are deposited in a continuous row, from 30 to 50, side by side, curving slightly around the stem with their heads toward the edge of the sheath, from which they are distant about one-third the circumference. The time occupied in actual deposition is from 20 to 40 minutes, but the selection of a location and the catching of a sheath edge often occupy several hours.

"Although the eggs were deposited through a period of two weeks or more they apparently all hatched at about the same time; the time evidently depending considerably upon favorable conditions of temperature and moisture, for, up to July 2, no larvæ had been observed either in the cages or in the field. On this afternoon the air was very oppressive, and remained so until cleared by a heavy thunder storm during the following night. On the morning of the 3d they were observed just emerging from the eggs in the cage, and examinations showed that they had hatched in the field also. The earliest deposition from which they were observed to issue on this date was made May 23, and the latest on June 9, while the majority were deposited June 4 and 5. This gives from 26 to 38 days, with an average of about 1 month, as the period of incubation.

"The freshly hatched larvæ have shorter and blunter heads than the adults, and are much more active, but within a week or two the head has elongated, and it has adopted the sluggish habit of the adult.

"Upon hatching, the larvæ immediately arrange themselves along the base and margins of the broad leaves parallel to the veins, where they remain stationary for weeks at a time, so closely resembling the rust spots and discolorations occasioned by their punctures that the chance of their detection is slight, or they ascend to the head, where they conceal themselves so effectually among the glumes and sheaths upon which they feed that one might carefully examine a head and pronounce it free from them, only to find, on shaking it violently, that it contained a whole colony. Here they stay until the head ripens in September, when they descend to feed on the second growth and the surrounding grasses until winter, when they crawl into the thick clump of the Elymus and hibernate, appearing again in early May and changing to pupæ. From then on until the middle of the month they feed on any green plant, near enough to be reached, crawling at last to the top of some blade of grass and issuing as adults over 10 months from the time of hatching from eggs.

"This species, in common with the others which occur in long and short winged forms, are usually very thick, where they occur at all; but the eggs, being deposited only upon the Elymus, they are limited in their range to a radius of a few feet at most from their host.

"They have been observed to feed upon the heads of *Elymus virginicus* indiscriminately with those of *canadensis* where the two grasses are near together, or near enough for migration, and in the spring, when the larvæ were large and abundant and the grasses small and inconspicuous, they were found upon everything occurring within a reasonable distance of the host."

Parabolocratus viridis Uhl.

Parabolocratus viridis Uhl. is a species of wide distribution, occurring from Massachusetts to northwestern Montana, and has been

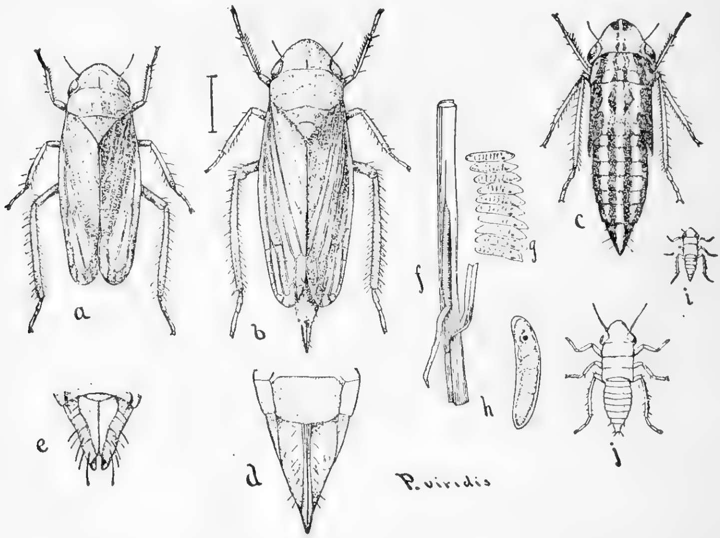

Fig. 8.—*Parabolocratus viridis:* *a*, Male; *b*, female; *c*, nymph; *d*, female genitalia; *e*, male genitalia; *f*, eggs in stem; *g*, eggs, enlarged; *h*, single egg, still more enlarged; *i*, *j*, young nymphs. All enlarged. (After Osborn and Ball.)

collected by many different observers, though usually in small numbers. So far as definite records go, it develops only on the wild oats (*Stipa spartea*). Except for collections extending its known range, scarcely any information has been gained since the publication of the life-history details in the Proceedings of the Iowa Academy of Sciences in 1897, by Osborn and Ball, and I can not do better than quote directly from the account published at that time:

"The adult female is about 7.5 mm. long by 2 mm. broad, with a parabolically curved, thin-edged vertex and a stout abdomen, attenuated posteriorly and extending beyond the rounding elytra. The males are smaller and have the vertex shorter and more obtusely pointed. The abdomen is smaller and does not extend beyond the narrow and nearly parallel-margined elytra. (See fig. 8.)

"They are both of uniformly deep-green color above, somewhat lighter below, with a narrow band under the sharp vertex, and the eyes dark; the exserted tip of the ovipositor orange-red.

"The first brood of adults appeared the first week in May and remained until the middle of June, disappearing gradually. They feed principally upon the leaves, usually about the middle, feeding on either side and either end up, with equal ease.

"The eggs are deposited during the last of May and the first week in June. The females, usually selecting a position just above the first leaf base and invariably placing themselves head downward, exsert the ovipositor and insert it under the flap of the sheath, gradually working backward up the stalk for a distance of 2 inches or more and depositing from 70 to 120 eggs within an hour.

"The eggs are 1.23 mm. long and 0.25 mm. broad, cylindrical, of nearly uniform size, curving considerable around the small stem.

"The larvæ appeared the last week in June, giving an incubation period of 15 to 20 days. Upon bursting the egg-case the larvæ crawl partly out from under the sheath and remain quiescent in this position for an hour or two when, becoming suddenly active, a flock of small larvæ may be seen ascending the stalk and distributing themselves upon the leaves, while a row of freshly shed skins, with the abdomen still remaining under the sheath, their tips scarcely free from egg-shells, explains the cause of the delay.

"They require about a month to develop, maturing during the latter part of July and the first of August, the adults remaining until the middle of September.

The host plant is variously estimated, in some instances being considered a troublesome, dangerous weed, in others as a valuable forage plant. In parts of North Dakota especially I was informed that the stock raisers prize it and cut and feed it regardless of the stiff barbs. It appears earlier than some of the other grasses, thus supplying early grazing, and if cut early before the development of the long barbs, must make a good quality of hay. Early cutting has also the advantage of destroying the eggs of this leafhopper and its scarcity may be due to such destruction—mowing closely between the 10th and 16th of June in Iowa, and relatively later farther north will destroy the first brood of eggs and dispose of the barbs, giving a later growth of nutritious grass free from jassids. Should adults appear in numbers in August, a second mowing in the latter part of this month should dispose of the second brood of eggs.

The Sharp-nosed Leafhopper.

(*Platymetopius acutus* Say.)

The sharp-nosed leafhopper (*Platymetopius acutus* Say) is one of the species that has an almost universal distribution throughout the United States, and while it has never been reported as occurring in

such numbers as some of the other species, it can hardly be overlooked in a discussion of the species of economic importance. It was recognized and described by Say nearly a century ago and has had quite frequent mention in scientific papers, but no discussion of habits or description of early stages until 1897, when it was treated in a paper on the species occurring in Iowa.

The adult insect (fig. 9) is distinguished by a remarkably long, pointed head, and narrow, elongate face, a brownish-gray color, with very numerous round white points on the wings and with a row of black cross-veins on the border. It is about one-fifth inch in length. The larvæ are similar to the adults in shape, having a very much elongated head, narrowing to an acute point, and when full grown they are about one-sixth inch long. They are characterized particularly by a broad light stripe along the back, passing from the tip of

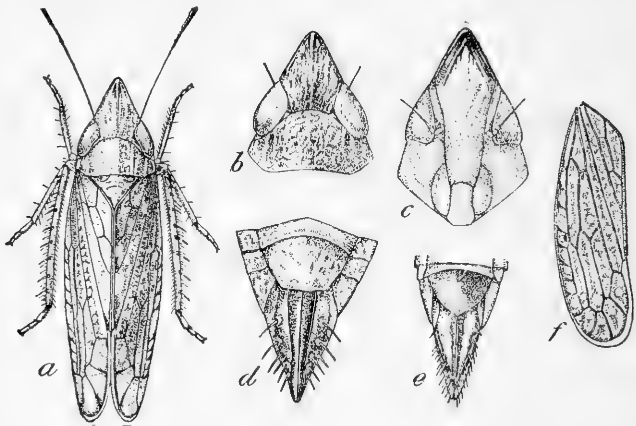

FIG. 9.—The sharp-nosed leafhopper (*Platymetopius acutus*): *a*, Adult; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, elytron. All enlarged. (Original.)

the head across the thorax, where it widens, and narrowing on the base of the abdomen and expanding on the central part and again on the extreme tip. This stripe is bright red on the center and shades into a creamy white on the margin. It is sometimes divided on the abdomen into two spots, one on the central portion and another at the tip. A black stripe extends along each side the entire length of the body, the stripes meeting below the tip of the head. It includes numerous minute white spots underneath a creamy white.

The young are first noticed during the latter part of May and mature before the end of June, the adults beginning to appear by the middle of June and continuing until the middle of July, the nymphs of the second generation appearing in July and maturing in August, while the adults of this second generation are found from the middle of August until into October. Apparently these lay eggs in autumn, which survive the winter to hatch in spring. The young are found in grassland, but more commonly in shady situations, and the adults are to be found quite generally distributed on different kinds of

grasses or on low vegetation and appear to be general feeders. They have not been determined as restricted to any single kind of grass as a host plant.

The Yellow-faced Leafhopper.

(*Platymetopius frontalis* Van D.)

The yellow-faced leafhopper (*Platymetopius frontalis* Van D.) is a much darker species than the *acutus*, ranging from dark brown to distinctly black with a broad border and lemon-yellow face. The forewings are marked with numerous round, white spots. In size it is somewhat shorter but more robust than *acutus* and the head is not so long or so sharply pointed. (See fig. 10.)

The young, which resemble the adults in shape, have a broad, light-yellow or creamy colored stripe occupying the large part of the back, but leaving a marginal dark border somewhat like that of *Deltocephalus inimicus*, but in this species the marginal stripe expands on the head in front of the eye. The life history of the species is similar to that of *Platymetopius acutus*, the nymphs appearing about the last of May and being found through the most of June, and adults occurring from the middle of June on nearly through July. The nymphs of the second generation appear by the middle of July and occur until the latter part of August, while the adults of this second generation begin to appear about the middle of August and are found abundantly through September into October, presumably depositing eggs, which survive the winter, as adults are not to be found late in autumn or early in spring. This species seems to prefer shaded locations, as it is usually found much more plentiful in the vicinity of thickets or coarse weeds, but it occurs also in rather rank grass, clover, etc., in pastures or meadows. The nymphs are swept from the undergrowth of grass and weeds.

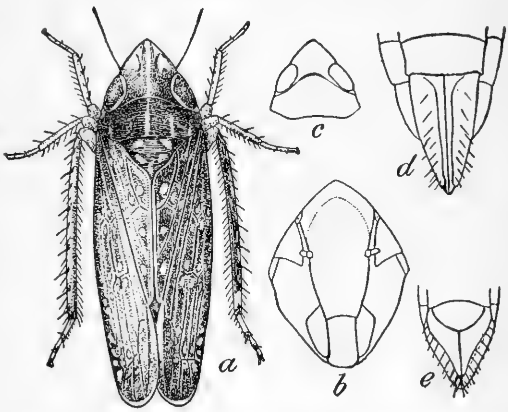

Fig. 10.—The yellow-faced leafhopper (*Platymetopius frontalis*): *a*, Adult; *b*, face; *c*, vertex and pronotum of male; *d*, female genitalia; *e*, male genitalia. All enlarged. (Original.)

The species has a very extended distribution in the United States, ranging from eastern Canada to New York and to Illinois, Iowa, and Kansas, and it occurs in many cases in considerable abundance, so that it may properly be considered as of economic importance.

While perhaps not so destructive as to require particular discussion of remedies, it may be said that it would be affected by the same treatment as that applied to the other grass-feeding species, but would not be destroyed quite so commonly in the treatment applied to the short grass of pastures or to closely mown fields.

Platymetopius cinereus Osb. and Ball.

The species *Platymetopius cinereus* Osb. and Ball has not been observed for anything like the extent of range or abundance noted for the other species mentioned, but in a few instances has been found to occur in considerable numbers. It is a smaller and lighter colored species than *acutus*, the female being only about one-sixth inch in length and the male still smaller. The larvæ are distinguished from those of *acutus* by the absence of the red color and the dorsal stripe, and from those of *frontalis* by the much more elongate form.

The nymphs of this species have been observed early in June, but nearly full grown, so that they must have been developing during the latter part of May, and by the middle and latter part of June they are replaced by adults, which are found in decreasing numbers until after the middle of July. Nymphs of a second brood are noted by the last of July, and remain in abundance up to the middle of August. These again are replaced by adults which begin to appear by the second week in August and continue on through September. The species is known from Iowa through Nebraska and Kansas to Arizona. It appears to develop especially on three different kinds of grasses, *Andropogon scoparius*, *Bouteloua hirsuta*, and *B. curtipendula*, the latter two species probably being its most common hosts. It is therefore more particularly of importance in the plains region, where the wild grasses form an important part of the forage, and so far as known need not be considered as of importance to the ordinary cultivated grasses of the Mississippi Valley or the Eastern or Southeastern States.

The Inimical Leafhopper.

(*Deltocephalus inimicus* Say.)

The *Deltocephalus inimicus* of Say (figs. 11, 12) is one of the most widespread and injurious species among the leafhoppers, but nevertheless it has received comparatively little notice in economic literature. It was first described in 1831 by Thomas Say, who states in connection with the description that when in the larval state this species is said to depredate on the roots of wheat. "Several specimens were sent me by Prof. Green, in the year 1822, who received several from a farmer in Virginia." This would place the recognition of the species as an injurious pest as far back as 1822, nearly a

century ago, but the next mention of it from an economic standpoint appears to have been in 1884, when Prof. Forbes speaks of it as occurring in corn and also injuring wheat in connection with two other species of leafhoppers which he described in detail. Dr. Fitch merely mentions it in his list published in 1851, but does not seem to have recognized its economic importance. Other notice of it does not appear until 1890, when, in a report to the Division of Entomology, I called attention to its abundance and its destructiveness in Iowa in connection with other insects. I also described the general appearance of the larva in 1891 and published some details of the life history in 1892 and 1893. Also, in Bulletin 19 of the Iowa Agricultural Experiment Station, I described the treatment for it, especially with the hopperdozer. Prof. F. M. Webster, in 1896, mentioned the life history, etc., in Bulletin 68 of the Ohio Agricultural Experiment Station.

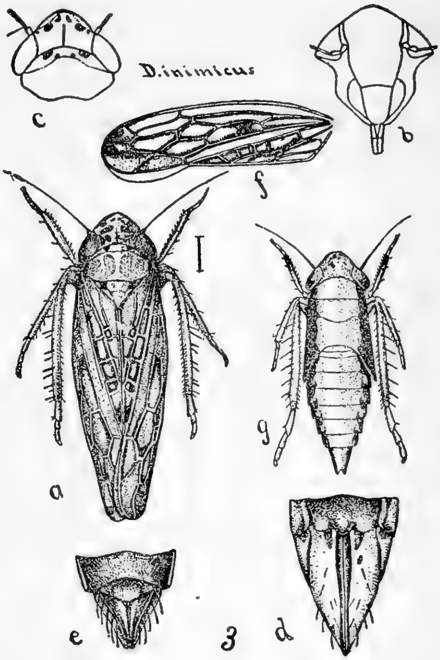

FIG. 11.—The inimical leafhopper (*Deltocephalus inimicus*): *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, elytron; *g*, nymph. All enlarged. (After Osborn and Ball.)

DISTRIBUTION.

The species is one of very wide distribution in America (see fig. 13) and appears to be confined to this country. Van Duzee, in his catalogue, credited it to Canada and the United States west to the Rocky Mountains, but later records indicate its general occurrence all the way from Maine to Washington State and south at least to Tennessee and southwest to Kansas.

In the summer of 1909 I found it on grass at Ames, Iowa; in the Missouri Valley in grass, timothy, wheat, and alfalfa; in South Dakota at Vermillion, and at Brookings in wheat, bluegrass, timothy, and wild grass; in North Dakota at Fargo, June 25 to 28, full-grown nymphs and adults, in pasture, especially an old brome-grass pasture and a timothy-clover pasture. At Ada, Minn., July 2, in wheat fields and grass; at Dickinson, N. Dak., July 8, in alfalfa; at Mammoth Hot Springs, Yellowstone Park, July 14, in irrigated plat (?); at Bozeman and Missoula, Mont., July 15 and 16, on grass; at Moscow, Idaho, and Pullman, Wash., on timothy, festuca, and alfalfa; at Kalispell,

Mont., July 24, on grass; at Williston, N. Dak., in wheat, oats, alfalfa, and clover, and in brome grass of second-year planting; at Devils Lake, N. Dak., on bluegrass and timothy, and at Grand Forks, N. Dak., on bluegrass (lawn) and in a stubble field, including red-top and clover; at Castalia, Ohio, August 13, abundant in bluegrass and volunteer wheat, and at Toledo, Ohio, August 27, in bluegrass pasture and field of Hungarian grass; at Columbus, Ohio, September 1 and 16 and October 8, in bluegrass, and at Akron, Ohio, September 11, in stubble field (wheat), including timothy and clover; at Wooster, Ohio, September 14, in clover, alfalfa, and low-ground pasture and in plat of mammoth millet; at Urbana, Ill., September 28, in a timothy and clover field; at Lafayette, Ind., October 4 and 5, in bluegrass pasture, in alfalfa, on volunteer wheat, in clover, and in

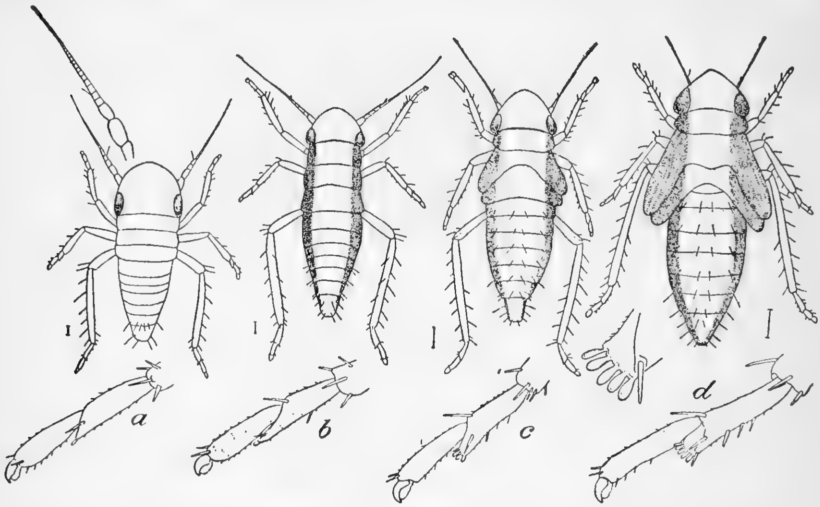

FIG. 12.—The inimical leafhopper (*Deltocephalus inimicus*): Nymphal stages; *a*, newly hatched; *b*, *c*, *d*, later stages, the details of tarsal appendages shown below. All enlarged. (Original.)

a wheat plat, newly started; at Fort Benjamin Harrison near Lawrence, Ind., October 6, in stubble field, including mixed grasses, clover, and other vegetation; at Hamburg, N. Y., October 20, in wheat, new growth, and at Valencia, Pa., on November 2, in new growth of wheat; at Harrisburg, Pa., November 5, none in wheat but a few in grass; at Reading, November 6, in grass and a few in wheat; at Newark, Del., November 9, in wheat (a few) and in grass; at College Park, Md., November 11, in grass and only a few in wheat, oats, and barley; at Arlington, Va., November 12, in grass and wheat; at Washington, D. C., November 13, in grass; at Knoxville, Tenn., November 22, on bluegrass, orchard grass, and fall barley. In June (22–24), 1910, it was found abundant at Mackinac Island and Sault Sainte Marie, Mich., both in wheat and grass. Nearly all taken were

in the nymphal stages, ranging from those recently hatched to mature, but a few adults also were secured.

Its particular habitat is throughout the country where bluegrass is the common pasture grass, and this is, perhaps, its favorite food plant. So generally distributed is it that it is almost impossible to sweep over any patch of bluegrass anywhere from Maine to Washington without finding representatives of this species among the leafhoppers that are captured. Throughout most of this territory it is usually the most abundant of the species taken, and in many cases it far exceeds all other species in numbers. In the statement of relative abundance, written by Mr. V. L. Wildermuth in another

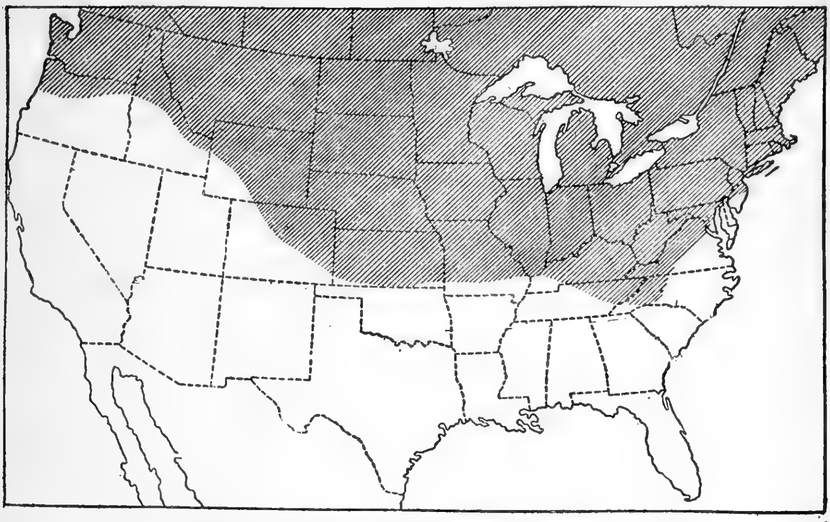

FIG. 13.—Map showing distribution of *Deltocephalus inimicus*. (Original.)

place (pp. 14-15), it will be observed that this species may comprise about nine-tenths of the numbers captured. While bluegrass and timothy are the more common food plants, the species has a wide range and has been observed on wheat, oats, corn, millet, rye, clover, alfalfa, and a considerable number of wild grasses of the plains region. This general occurrence on different food plants makes it possible for the species to survive in almost any locality, and it is thus given abundant opportunities to migrate to any favorable crop which may grow within a reasonable range.

LIFE HISTORY.

(Figs. 11, 12.)

Although the larva was mentioned by Say in his original description, no study of the life history seems to have been made until 1892. General descriptions of the different stages are given in Bulletin No. 30 of the Bureau of Entomology and in Bulletin No. 20 of the

Iowa Agricultural Experiment Station. The eggs are deposited in the leaf or stem, especially beneath the epidermis of bluegrass, and cause very minute, blisterlike swellings. These, for the winter generation, remain until spring and hatch, for the latitude of Iowa, in the latter part of April and early May, there being some variation according to season. This generation matures by the latter part of June or early in July and adults occurring early in July deposit eggs which hatch within a few days, producing nymphs of the second brood in the latter part of July. These mature by the latter part of August, and adults are usually encountered from this time on until winter, although scattering nymphs are likely to occur during the autumn months. No proof, however, is available of a definite third brood for the season, and eggs deposited by adults in autumn survive the winter to renew the cycle the following year.

During the growth of the nymphs five distinct stages have been observed, the first of which, the newly hatched nymph, is rather short, with a very prominent head and a small abdomen, and without clear markings. The second stage differs in a more elongate form of body and a definite black border along the sides of the thorax and abdomen. The third stage differs from the second only in the appearance of the wing-pads, and from this stage on through the fourth and fifth stages the change consists merely in a greater intensity in coloring and relative increase in size of the wing-pads. At the end of the tibia of the hind legs there is a peculiar microscopic spatulate structure that occurs in varying numbers from the newly hatched nymph to the adult form. In the specimens studied and figured there were for the first instar one, for the second instar two, for the third instar three, for the fourth instar five, and for the adult insect five. The adults are gray, with dark brown or blackish markings. A very constant feature is the presence of three pairs of black spots, one on the vertex, one on the pronotum, and one on the scutellum. The length is about one-fourth of an inch.

The molts occur at intervals of seven or eight days in examples observed in rearing cages and in some instances the development from the newly hatched nymph to the adult occurred in 32 days. The time of incubation for some eggs has been determined as not longer than 17 nor less than 10 days. This, however, was confined to jars, and it is possible that under outdoor conditions the rate of development may be more rapid. A record by Prof. Webster of observations on the development of the species adds some further information and may be introduced here for comparison.

Several years ago, on November 11, a number of adults were placed on young wheat plants that had been reared indoors, and hence were free from affection by insect attack. The females began at once to oviposit in the tissue of the leaves, and the young could be observed developing within the eggs, especially after they had become well advanced. Young were especially noticeable just prior to their emerging by their eyes being jet black. The young molted a few days after hatching, and, so far as I

could observe, but twice afterwards. December 22 one of the first individuals to appear molted for the last time, and on the following day adults were out in numbers. It will be observed that 41 days were required for the development of the insect from egg to adult. It is not unlikely that the species hibernates in the egg state in the leaves of grass, though it would seem probable that it may also live over as adults. My wheat plants were kept growing in glass tubes, probably an inch and a half in diameter, and in a temperature of probably not far from 70° F. (Webster, Ohio Agr. Exp. Station Bul. 68, p. 43, 1896.)

TREATMENT.

There is not much to be added to the discussion of general treatment, as this species is one of the most widely distributed and is open to every remedy which has been advised for the leafhoppers in general. The fact that it is primarily a grass insect and that it attacks wheat, oats, and other grains incidentally, makes it possible to restrict its injuries to other than grass crops by attention to the fields adjacent to such cultivated crops. The burning of grass along the sides of the field, in fence corners, or along roadsides would in a large degree protect wheat fields from the fall migrations. The species is readily caught in the hopperdozer, and in pastures or permanent meadows where burning is not considered desirable this or the application of an insecticide by spraying is probably the most available remedy.

The Black-faced Leafhopper.

(*Deltocephalus nigrifrons* Forbes.)

The black-faced leafhopper (*Deltocephalus nigrifrons* Forbes) is an abundant and very widely distributed species, occurring in a very perplexing number of variations, so that it has received several different technical names. It was first described by Prof. S. A. Forbes from specimens found depredating in wheat and oats, but no details of life history were given and, apparently, no detailed study of its habits or distribution. Since then little has been done in the way of working out its habits and, aside from a publication of a record of its occurrence on different food plants and a description of the lymphal stage in 1907 by Osborn and Ball, very little has been published.

It is one of those perplexing aggregations which are the despair of systematic workers and which are excellent examples for the evolutionist, since the different variations run off into such extreme forms as to indicate the possibility of incipient species. We need not consider in detail the systematic problems, however, as apparently for this species these do not have any very great economic significance. If it were a question of the economic importance of separate varieties this question might be much more essential. So far as determined, however, all of the forms will migrate readily from one plant to another and consequently no restriction corresponding with these variations is to be considered.

DISTRIBUTION.

The distribution of the species, as here limited, covers a large part if not the entire territory of the northern and eastern United States, as material has been examined all the way from New York to Washington, D. C., and south to South Carolina and Georgia, and west to New Mexico. In this distribution there seems no particular limit to the different varieties, but any of them may occur within the different territorial limits.

FOOD PLANTS.

It has a considerable range of food plants, but there is apparently a quite distinct preference for the annual grasses, such as foxtail or panic grasses and others, but it migrates very readily from these into wheat, oats, and other cereals and also occurs very commonly in bluegrass and timothy, especially after the withering of the annual grasses upon which it has fed earlier in the season. On this account it is one of the most troublesome forms occurring in fall wheat and oats, since it has developed in great numbers upon early grasses and with the failing of these as a food supply is forced to migrate, and this migration, coming with the appearance of the young and succulent plants of wheat and oats, affords the most attractive bait.

DESCRIPTION AND LIFE-HISTORY NOTES.

The adults (see fig. 14) are to be recognized by the rather short vertex, the margins of which are plainly rounded, and especially by a distinct row of black spots which lies next the border of the upper part of the head and bends down alongside the eyes in front. Of these spots there are four on the upper part between the ocelli, usually one on each ocellus, and two on each side between the ocellus and base of the antennæ. Other spots may occur with greater or less distinctness on the upper part of the head, but are too variable to constitute good characters for recognition. The face is usually marked with numerous black bars; sometimes it is entirely black or with only a few light streaks on the lower portion. The upper part of the body, the thorax, and the wings vary greatly in intensity of color, sometimes being very light, occurring without any distinct markings, and sometimes presenting distinct dark-brownish markings, especially along the veins of the forewing. The forewing presents a peculiar diversity in the development of the cross veins, some examples presenting two distinct veins, while others, apparently identical in every other respect, are wanting in the hinder one of these cross veins. These two forms not only agree in other respects but are evidently derived from nymphs which are idistinguishable.

The nymph is rather broad and resembles in characters the *Deltocephalus flavicosta*, but is slightly narrower and not so distinctly

marked. It is yellowish in color, has two black dots on the margin of the upper surface, and often two oblique dashes on the disk. The last nymphal stage further presents very distinct spots—those on the front margin of the wing pads and a number on the hinder end of the disk which are more or less distinctly arranged in transverse rows. The nymph is not very readily separated from that of *Athysanus exitiosus*, but the latter species has black spots on the head farther down upon the front. The nymphs of this species appear in early summer and the adults are usually to be found in numbers by the first of July. These adults deposit eggs and the nymphs from these develop during July and August, and adults appear in September and are to be found on into October and November and in localities farther south will be taken in numbers as late as during November and early December. In fact, they seem to remain active until severe cold weather forces them into inactivity.

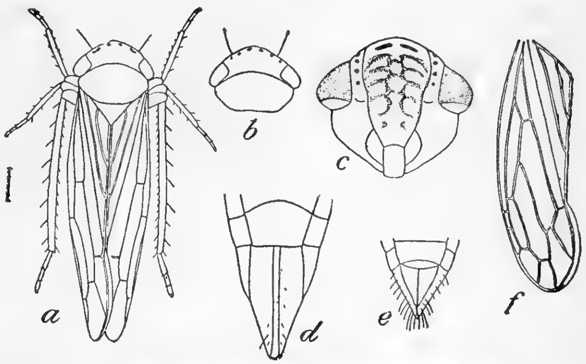

FIG. 14.—The black-faced leafhopper (*Deltocephalus nigrifrons*): *a*, Dorsal view; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, wing. All enlarged. (Original.)

MEANS OF CONTROL.

The method of control for this species may be based directly upon the migratory habit of the species and especially upon the fact that it develops so largely in the field grasses which are either worthless or noxious in character. In many places the mere elimination of foxtails and panics which grow along the borders or in neglected cornfields would greatly reduce the numbers of this pest, and in some instances it would be entirely practicable to burn the borders of fields, where such grasses are beginning to wither, in time to kill the hoppers which may occur there. In the Southern States, especially where fields are often interspersed with strips of uncultivated ground, the burning or even close mowing of such strips would doubtless be of considerable service in preventing injury to fall wheat and oats. Additional knowledge concerning the actual method of deposition of eggs may add to the possible measures for control.

DELTOCEPHALUS SONORUS Ball.

The species *Deltocephalus sonorus* Ball is one of the *nigrifrons* group, but is uniformly smaller and more slender, and the spots on the border of the vertex are quite constantly arranged so that there is a small

one near the tip of the vertex and a larger round one above the ocellus, usually quite conspicuous. The color is pallid and the veins are usually but slightly apparent; the wings extend beyond the abdomen; the length is about 4 mm.

This species occurs upon the annual grasses and has a very general distribution, especially in the southern part of the United States, from Florida to southern California. It sometimes appears in great abundance, as shown by the collections of Mr. C. N. Ainslie in Texas and New Mexico, and by the writer in California, and may be a distinctly economic species passing from annual grasses or weeds to cultivated crops. The most evident method of control, with our present knowledge of the species, is the elimination of the host grasses during the early part of the summer.

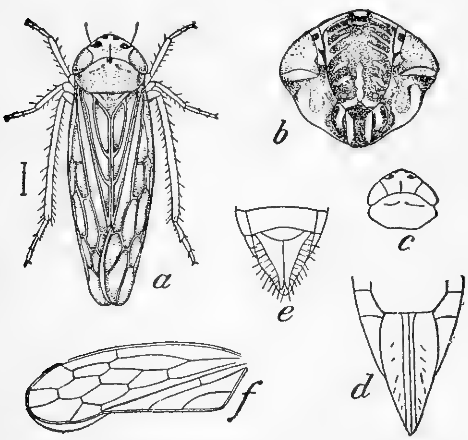

FIG. 15.—*Deltocephalus fuscinervosus*: *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing. All enlarged. (Original.)

DELTOCEPHALUS FUSCINERVOSUS Van D.

Deltocephalus fuscinervosus Van D. is a southwestern form closely related to *D. nigrifrons*, but with darker coloration above and a more complete fusion of the spots on the vertex. (See fig. 15.) The genitalia are quite similar, and it is probable that the two forms stand as divergent branches from a common stock.

This form occurs abundantly in the wild grasses of southern California and is found as far north as San Francisco.

DELTOCEPHALUS CONFIGURATUS Uhl.

Deltocephalus configuratus was described in 1878 by Prof. Uhler from specimens which were collected in one of the geological surveys through the Rocky Mountains region, but no intimation was given of its economic importance and no statement of any such importance occurs until the report on the work of Iowa species in 1896. At that time it was recognized as important, as it was taken in great abundance in both the nymphal and adult forms in grasses. The species has a wide distribution throughout the northern part of the United States and probably in the southern portion of Canada. Records from various sources show it to occur from Mount Washington, N. H., through New York and northern Ohio, Illinois, Iowa, the Dakotas,

Wyoming, and Montana. At Tower City, N. Dak., it was reported in 1901 and 1905, evidently occurring in abundance in grasses, as collections included large numbers of both males and females. In New York it was stated by Van Duzee to be "a common meadow insect from May to August, but in the year 1904 I did not find it in any numbers except at Hamburg, although I collected at a number of different points in that State. Probably, however, my collections were made a little too late in the summer to find it at its greatest abundance. In 1909 I found it quite common at Brookings, S. Dak., June 20 and 25, especially in wild grasses, and at Fargo, N. Dak., it was the most abundant species for this and the succeeding month in an old pasture of brome grass. It occurred at the Mammoth Hot Springs, Yellowstone Park, Wyo., July 9, on native grasses.

It is one of the largest species of the genus Deltocephalus and is easily recognized by the broad blunt head as well as by the peculiar structure of the genitalia. (See fig. 16.) The last ventral segment of the female ends in a narrow black process divided at the tip, and the male plates are large, broad, and obliquely truncate. The forewings are usually longer than the abdomen, but vary in length in different individuals.

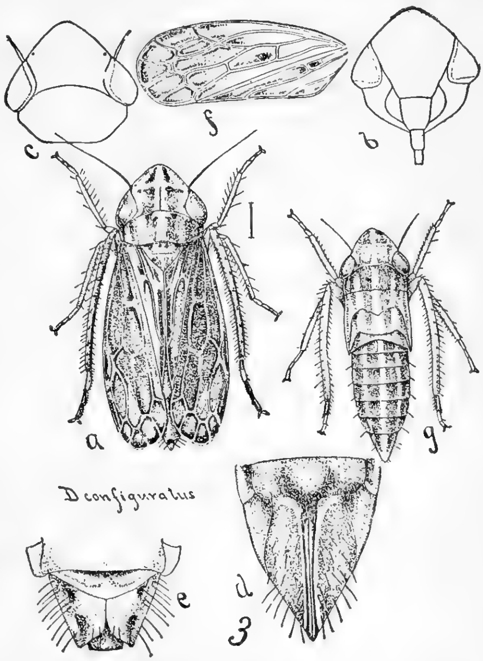

FIG. 16.—*Deltocephalus configuratus*: *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

The nymphs have a broad head, the front of which is rounded and marked with brownish bars. They are pale brown above, with three indistinct stripes and a row of dots just within the narrow light border on each side of the abdomen. The full-grown nymphs were first taken in Iowa early in May along with adults that had apparently just issued from the nymphal stage, and within two weeks the nymphs had all matured and adults were very abundant throughout June and a few occurred in early July. At the time the observations were made in 1906 the field in which they were made, and which was under observation throughout the whole season, was mowed June 25; the only specimens indicating a second generation were some half-grown

nymphs occurring July 16. While this record would indicate two generations each year, it indicates also the fact that an early mowing in May coinciding with the time at which the species occurs in the egg form in the stems of grasses would effectually control it. Other species of the genus, the egg deposition of which occurred at a different period, were not so completely exterminated as this one. The results in this case, however, would seem to show that mowing, at a time when the eggs occur on the plants, may be a very effectual method of reducing the numbers of this species, which has a definitely limited period of egg deposition. It would, of course, be open to the same

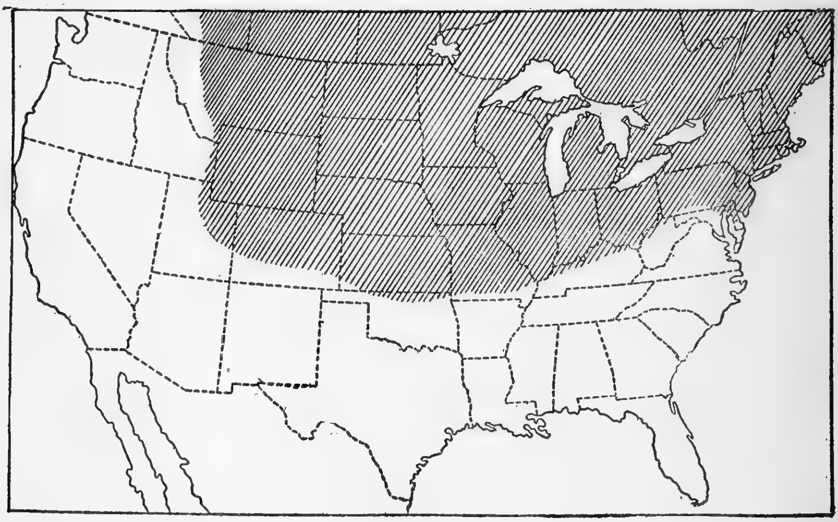

FIG. 17.—Map showing distribution of *Deltocephalus affinis*. (Original.)

methods of destruction by hopperdozer, spraying, and burning as any of the other species.

DELTOCEPHALUS AFFINIS Gillette and Ball.

The species *Deltocephalus affinis* has been discussed under the names *debilis* and *melscheimeri* in earlier articles, but it is first mentioned as an economic species in a report of the Division of Entomology, United States Department of Agriculture, in 1890. It was an extremely abundant and apparently destructive species in Iowa during a number of years when it was observed in that State. It occurs in greatest abundance in bluegrass in lawns and upon pastures or meadows, showing a distinct preference for open and sunny situations rather than shaded locations. It was abundant in both wheat and grass at Sault Ste. Marie, June 23 and 24, 1910, mainly in the adult stage.

DISTRIBUTION.

It has a very extensive distribution (see fig. 17), having been reported under various names from the New England States and

throughout the northern United States and southern Canada and is evidently a form that was reported by Dr. Wm. H. Ashmead under the name *harrimani* from Alaska (report of Homoptera, Harriman Alaska expedition).

DESCRIPTION.

The adult insect is of a light gray or brownish-gray, often pale, but varying so much in color that it has been many times described under different names. It is nearly one-sixth of an inch long and is to be separated from *D inimicus* by the absence of definite black spots on the head and thorax and by the slightly smaller size. The head, too, is a little more distinctly pointed. (See fig. 18.) The most positive characters are found in the genitalia, the last ventral segment of the female being short, nearly straight on the hind border, while the male valve is very much enlarged and convexly rounded, almost covering the plates, the tips of which appear as slight projections beyond its hind border.

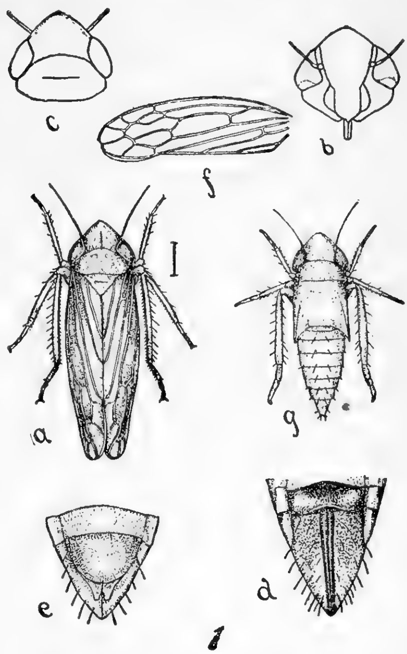

FIG. 18.—*Deltocephalus affinis*: *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

The nymphs are of about the same form as those of *inimicus*, but differ distinctly in that the body is uniformly light yellow without the black lateral border which is characteristic of *inimicus*. The head is bluntly angled in front and in the later nymphal stage the wing-pads expand in a rather sharp angle back to the second abdominal segment.

LIFE HISTORY.

The life history of the species has not been determined with complete accuracy and is difficult to establish because of the irregularity with which the different generations appear and the overlapping of adult and nymphal stages. From observations in Iowa it was believed that there might be three or possibly four generations each year and the designation of the broods so far as they could be determined showed adults from the middle of May until the last of June; nymphs

from the first week in June until the middle of July; adults, again, from the first week in July through August; nymphs through August until the middle of September, and again adults from the middle of September through the season. The evidence is therefore very strong that eggs are deposited in autumn, survive the winter, hatch in early spring, and developing as nymphs during April or early May reach the adult condition, as observed above, by the middle of May.

REMEDIES.

So far as observation or experiment goes the most satisfactory treatment for this species is the use of hopperdozers or sprays during the early part of the season so as to reduce the numbers and prevent injury during the latter part of the summer. From the observations in Iowa it appears that the most effective dates for the use of hopperdozers would be from May 25 to June 10, again from July 15 to July 25, and again, if the insects are still abundant, about August 10. As the eggs are quite certainly in the leaves or stems of dead grass during the autumn, winter, and early spring, it would seem almost certain that burning over the grassland where practicable would have a very positive effect upon this species. Of course this is not possible in some cases on account of the amount of green vegetation that would prevent the burning, and in other cases, if the grass is too dry, there would be danger of killing out the plants. Perhaps the best results would come from burning while the ground is frozen and at times when the upper portion of the grass is dry enough to carry fire.

SAY'S LEAFHOPPER.

(*Deltocephalus sayi* Fitch.)

Say's leafhopper (*Deltocephalus sayi* Fitch) is another widely-distributed species occurring in abundance in practically all kinds of grasslands throughout the northern United States, but showing a preference for bluegrass in woody pastures. It seems to have little preference for upland or low ground except as the grass becomes dry in midsummer, when it will be found gathering more particularly in shady places or where extra moisture permits the grass to remain more succulent. It has been recorded or observed for localities all the way from New Hampshire to the Rocky Mountain region with records as far south as North Carolina, Kentucky, and Kansas, and it probably has a distribution farther south at least along the Appalachians. (See fig. 19.) Its numbers are sufficient to make it a considerable pest in pastures and meadows where it occurs, although it does not have the extreme abundance noted for *D. inimicus* or *D. affinis*.

The adult insects (see fig. 20, *a*) are small, robust creatures with a rather distinctly pointed head and with the fore-wings broad and

rather short in many cases, exposing the tip of the abdomen beyond the ends of the wings. They are dark brown in color with distinct light markings and a fairly distinct band across the wing-base and again back of the middle of the fore-wings. They are a trifle more than one-eighth inch in length.

The nymphs (fig. 20, *g*) are rather slender and have a quite distinctly angular head colored much as in the adult, but the arrangement of the markings is different. There is a narrow middle line of white extending from the tip of the head to the end of the abdomen, where it widens and nearly covers the tip. There is a broad stripe extending along the side from the eye back to near the tip of the abdomen and an indistinct narrow one from the inner margin of the eye broken by white spots, one on the hind edge of each abdominal segment; there

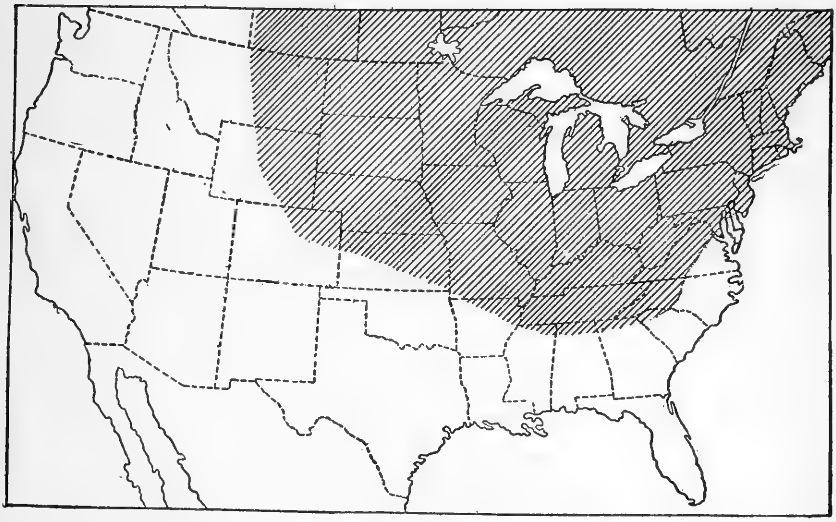

FIG. 19.—Map showing distribution of *Deltocephalus sayi*. (Original.)

is a second row of dots midway between the first and the marginal stripe on each side. In Iowa the nymphs were first found in small numbers on upland prairies the second week in June. They were full grown and probably somewhat later than the average as the adults had been taken during the first week of June and occurred in great numbers in watered pastures by the middle of the month. The adults were abundant from that time on through the season, but nymphs were again found on July 11 about half grown and full grown by the latter part of July along with fresh-looking adults. Nearly full-grown nymphs were again seen on the 5th of September and later in the month they were becoming rare while the adults were still plentiful. The adults probably survived some time after egg deposition, so that there is a continuous occurrence of adults to be noted throughout all of the latter part of summer. Egg deposition probably occurs in early October, as dissected females showed no signs of eggs the latter

part of the month. While broods are not very definitely separated it would seem from the observations made that the first brood of nymphs occurs from May until the early part of June, the adults of this brood from the last week in May until the middle of July, and the second brood of nymphs from the last week in June until the first week in August, while the second brood of adults, beginning to appear about the middle of July, extends through August; a third brood of nymphs, appearing first about the middle of August, develops during August and September, and the third group of adults, beginning to appear in early September, survives on through October. From this life history it is obvious that it will be difficult to fix upon any time at which mowing of the grass would be distinctly effective in exterminating the species, consequently we must depend upon the direct treatment of hopperdozers or sprays or the effect of general rotation of crops as the principal means of control.

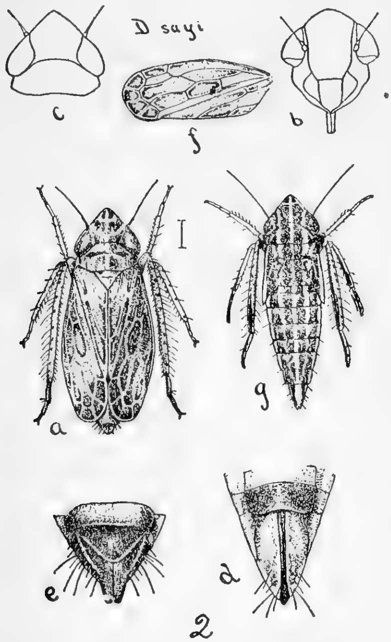

FIG. 20.—Say's leafhopper (*Deltocephalus sayi*): *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

This species has been found to be quite extensively parasitized by the small hymenopterous parasites of the family Dryinidæ. At one time at Cedar Point, Ohio, as many as about 20 per cent of the individuals collected showed the presence of the little external sacks of these parasites. Doubtless they constitute an important factor in keeping the species reduced in numbers throughout its range.

THE DESTRUCTIVE LEAFHOPPER.

(*Athysanus exitiosus* Uhl.)

Athysanus exitiosus was first given definite recognition as a destructive pest in the report of Prof. J. H. Comstock for the Department of Agriculture, in 1879, and in connection with his report there is given a technical description of the species by Prof. Uhler.

While it seems impossible that the injuries of the insect should have escaped previous observation, it is probable that they were referred to some other insect or that the insect itself was not connected definitely with this kind of injury.

This report mentions damage during the previous winter to grain in western South Carolina, parts of North Carolina, and Georgia,

with evidence that the leafhopper occurred in immense numbers and did great injury to the crops.

Prof. Comstock's account is so brief and covers the conditions at the time so well that it will be best to quote a few paragraphs of his article entire:

So many alarming reports were received during the course of the winter as to the extent of damage, that it was deemed necessary for me to visit the infested locality, which was accordingly done on my return from Florida about the first of March. In company with Mr. C. R. Jones, of the Charlotte Observer, I inspected several fields in the vicinity of Charlotte, North Carolina, and found that the accounts had not been exaggerated. In one infested field of ten acres, belonging to Mr. Geo. King, there was hardly one plant left to each square rod of ground. The diseased appearance most common in the wheat fields was a wilting of the outer leaves of the plant. Professor Uhler informs me that the customary method of injuring grass or grain is to pierce and suck the juices from the midrib of the leaf, and this method of work I have been able to confirm by an examination of leaves taken from the infested wheat. In a few cases I found the wilted leaves merely cut off at the base; this must have been done by some other insect.

In the wheat fields of Mr. W. W. Rankin the leaf-hoppers were at work in large numbers. There was observable on this plantation a most exact line between the eaten and uneaten portions. Instead of spreading themselves indiscriminately over the field, or half eating a patch here and there, they ate the wheat down to the ground as they progressed. In an eight-acre field six and one-half acres were utterly destroyed, while on the remaining acre and a half the crop was almost uninjured. It was, however, being rapidly destroyed. Here was apparently a good opportunity to watch them at their work, but it was impossible to do much on account of their extreme shyness, as they would fly upon the least disturbance. Professor Uhler has observed them about the time of oviposition resting on the midrib of a blade of grass or grain, with the head pointed toward the base of the leaf. The eggs are usually laid in the stems of grasses near the ground, judging from the known habits of allied species. The young hoppers when hatched are of almost precisely the same appearance as the old ones, except that they lack the wings. The time occupied in attaining full growth probably does not exceed a month, so that there are several broods a year.

Many erroneous opinions were given concerning the nature of this insect. Many considered it to be some form of the Hessian fly. Others, without attempting to name it, called it the fly of the maggot, which lives near the roots of the wheat. I was also informed by Mr. Jones that a theory was prevalent to the effect that the leaf-hoppers had spread from the cotton fields from the fact that similar insects were found in the dried cotton bolls. An examination, however, showed the cotton-boll insects to be a Psocus, often found in such situations, and which belongs to an entirely different order from the leaf-hoppers, the Neuroptera.

The great damage done the past winter was probably a result of the extreme mildness of the weather. Under ordinary circumstances the leaf-hoppers are kept in winter quarters and many are killed by cold weather. The present winter has been so warm, however, that they have been able to feed and reproduce continually. Moreover, the crops being in a young and tender condition, the effect of the work of the hoppers was infinitely more marked than it could ever be at any other season of the year. Under the ordinary conditions, then, of a moderately cold winter the ravages of this pest are not to be feared.

From our present knowledge of the habits of the leaf-hoppers, their injuries in mild winters in the more southern portions of the wheat belt will be very difficult to control. The only remedy which I have been able to suggest in answer to the urgent inquiries of the South Carolina farmers has been that used for the destruction of the allied leaf-hoppers on the grape vine, namely, carrying lighted torches through the infested

fields, at night, or building bonfires at different points. These insects are readily attracted by light, and great numbers will without doubt be destroyed. One or another of the trap lanterns mentioned in that part of this report relating to the cotton work could without much doubt be used to advantage if a number were mounted on posts in different parts of the fields.

A green leaf-hopper somewhat larger in size has recently been received from Laurens, S. C., with an account of its injuries similar to those given of the destructive leaf-hopper. It was identified by Professor Uhler as the *Diedrocephala flaviceps* of Riley, a species which did much injury to grain in Texas in 1876.

Other records in the Bureau of Entomology show it to have occurred as follows:

March 23, 1880, reported swarming in immense numbers at Cookesburg, S. C., on wheat fields.

January 29, 1880, specimens from South Carolina with statement that they were doing great injury to wheat.

March 20, 1880, from Laurens, Laurens County, S. C., and from the Charlotte Observer, Charlotte, N. C.

February 20, 1882, from Atlanta, Ga., in great numbers on oats about Albany, Ga.

October 8, 1895, from Columbia City, Ind., "Myriads of them occur in a wheat field."

February 28, 1880: "When disturbed, they fly 3 or 4 feet and alight. The wheat looks stunted and shriveled. Many of the outer leaves are yellow. Ten acres were perfectly bare, not one spear per square rod, wheat sown from the 15th of September to the 1st of December. Leafhoppers first observed this year Christmas time. Later at Charlotte, N. C., in wheat sown November 15, saw that something was the matter with the wheat a week or 10 days later—i. e., as soon as wheat was up. It has been an unusually warm winter, which had probably allowed the insect to increase."

May 4, 1889, from J. G. Barlow, Cadet, Mo., larvæ, which no doubt belong to this species, with report of much damage to timothy meadows which were sown the previous fall.

March 22, 1890, Athens, Ga., injurious to young barley.

November 15, 1897, Hawley, Okla., infesting wheat, a few of the blades turning yellow.

DESCRIPTION.

The adult insect (fig. 21, *a*) for this species is about one-sixth inch in length, the males being somewhat smaller than the females. The color varies from dark, nearly black (especially in individuals from the Southwest) to grayish-white, the wings especially being almost transparent but showing very distinct dark veins. The head is broad and the body tapers quite distinctly to the tip of the wings, the widest part of the body being about one-fourth the distance from head to end of body. The eggs which were secured by dissection from an adult female are about 1 mm. long and 0.05 mm. thick, distinctly enlarged near one end and tapering to a rather distinct, blunt point at the other end. They are placed in the leaves or between the leaf-sheath and stem of the plant.

Prof. Comstock states that the young hoppers when hatched are almost or precisely the same in appearance as the old ones except that they lack the wings. There is, however, a slight difference in the position of the spots on the head and in the proportion of the parts

of the body, the head appearing considerably larger in proportion, and this proportion decreases as the young insect develops. The head is broad, the eyes prominent, and there are two distinct black spots on the front portion of the head surrounded by a lighter circle, and the body is marked with grayish dots both on the thorax and abdomen. As the nymph grows the wing-pads develop at the sides and in the final stage extend back over the base of the abdomen.

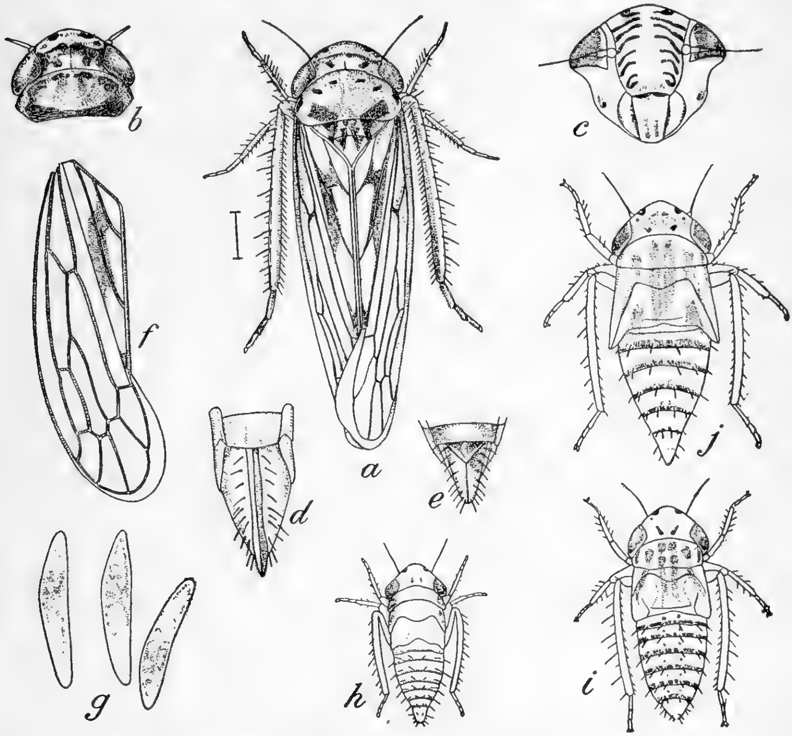

FIG. 21.—The destructive leafhopper (*Athysanus exitiosus*): *a*, Adult female, dorsal view; *b*, head and pronotum of male; *c*, face of female; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, eggs dissected from female; *h, i, j*, three stages of nymphal growth. All enlarged. (Original.)

These characters may best be seen in figure 21, which includes three nymphal stages.

LIFE HISTORY.

The adults of this species are found until late in autumn or even on warm days in winter, and in the Southern States doubtless remain active during a large part of the winter. It is probable, however, that the majority lay eggs there in late autumn or early spring. The nymphs develop in spring and mature individuals are to be found early in summer, and there are quite certainly two broods for all of the Northern States and probably three or more for the southern portion of the country. The exact limits of broods is not known and can not be readily determined because there is so much irregularity in the

time of occurrence of the different forms, in that adults and young of all stages may be found at almost any time of the year.

DISTRIBUTION.

The distribution of the species was given by Van Duzee in 1894 as from Maryland to Florida and west to Colorado and Texas, but later records have extended this distribution so as to cover practically all of the United States and portions of Mexico and the West Indies. During the year 1909–10 I found it in abundance at almost every point where collections were made from the Dakotas to Washington and in the Eastern States from New York to Georgia, and Southwest it swarmed in almost every locality from Texas to California, being one of the most abundant species met with in collections from grass, wheat, oats, and fall rye. It is quite probable that this is a southern species that has spread over the northern United States in comparatively recent times, but it is now well established. Evidently it is to be considered one of the most important of all the jassids when its wide distribution and possibilities for multiplication are taken into account.

MEANS OF CONTROL.

The control of the species is a matter somewhat difficult for grasslands, although it can be captured in the same manner as other common leafhoppers, but the attacks on grain, especially upon fall wheat, rye, barley, and oats, ought to be very readily prevented by attention to the adjacent grasslands at the proper time in midsummer or early autumn before the appearance of the growth of the fall grain crops. If it is appreciated that these jassids develop entirely during the summer months in the pastures or meadows or grasslands adjacent to the cultivated fields, it will be seen that the proper basis of treatment is to attack them in these adjacent fields. While they may not appear remarkably abundant or seem to cause great injury in the grasslands, they are, nevertheless, draining the crop extensively, and when these plants begin to ripen or become less succulent the tendency is for the leafhopper to migrate into the grain fields. Since they fly very readily they accumulate in large numbers in the grain fields and consequently produce the very marked injuries that have been described. The treatment of the grassland will depend largely upon what the nature of the land is and its importance as pasture or meadow. If practicable, it may be sprayed or treated with the hopperdozer, but for rough land, especially that which is not of importance for pasture, probably the most available method would be to burn over as completely as possible in September or at about the time that the grain crops are planted. Of course some of the adults might escape by flights, but at this time a large number of the insects would be in the nymphal stages and unable to fly, and consequently

unable to escape from the fire. The method suggested by Prof. Comstock, of utilizing lights to which they are attracted, may prove of considerable advantage, but there has been no careful experimental test of the effect of this kind of treatment.

Athysanus curtisii Fitch.

The species *Athysanus curtisii* Fitch is one that is quite widely distributed throughout the northern part of the United States and, while not occurring in such enormous numbers as some of the related species, is a very constant factor, breeding especially in woodland pastures and living upon several different species of grasses. It was described by Dr. Fitch in 1851 and evidently recognized by him as having economic importance although he gives no details of its life history. It was discussed, among other species of grass-feeding leaf-hoppers, in the bulletins of the Iowa Agricultural Experiment Station issued in 1891 and 1892 and the brief description of the nymphal form by Osborn and Ball was published in the Proceedings of the Iowa Academy of Sciences in 1897.

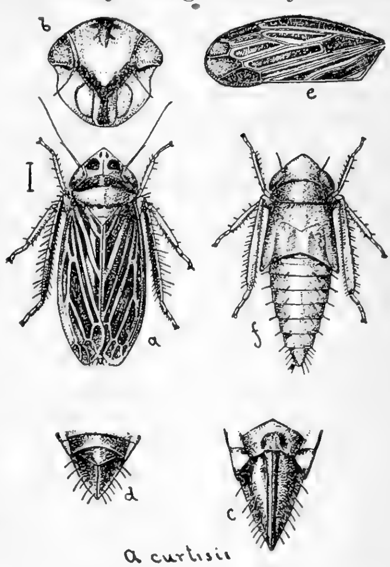

Fig. 22.—*Athysanus curtisii: a*, Adult; *b*, face; *c*, female genitalia; *d*, male genitalia; *e*, elytron; *f*, nymph. (After Osborn and Ball.)

The adult insect is 3.5 mm. in length, in body rather short and robust, the wings extending slightly beyond the tip of the abdomen. In color the head is yellow above, with two large, round, black spots above the middle, and the tip of the head is also black. The face is yellow, with an oblique black band passing from the eye to the base of the clypeus, from which it extends to the tip, forming for the whole face a Y-shaped mark. Above, the thorax is yellowish-green, with a black crescentic mark in front and the wings are dark, with distinct yellowish-green stripes. In the nymphal stage this species is stout, with a convexly conical head. The color is rather dark yellow and the eyes and antennæ are black. There is a rather dense covering of rather long hairs. (See fig. 22.)

The adults of this species appear in June and the nymphs are found during July, apparently completing their growth by the latter part of this month, and the adults are found in abundance during midsummer.

Another brood of nymphs appears during September and adults from these may be found during the autumn months, becoming abundant

in late September and mostly disappearing by the last of October. It would seem that the eggs are deposited rather early in the autumn as the adults are not found as late as those of some of the species of Deltocephalus.

The species is open to the same methods of attack as *Deltocephalus inimicus,* and for the most part the time of application would coincide very closely.

ATHYSANUS BICOLOR Van D.

The species *Athysanus bicolor* Van D. has been observed more commonly and in greater abundance in southern localities than to the north, and is evidently a member of a subtropical fauna, as its distribution extends southward from the Southern States into Mexico and Central America, where it has been observed as far south as Guatemala. Its northern range is probably about to the Great Lakes, as it has been found in Maryland, Ohio, Illinois, and Iowa, west to Kansas, and then southward. Its range of food plants has not been determined with any completeness, but it does not appear to occur with any frequency on the cultivated species of grasses or grains, and hence has not the same economic importance as some of the other species.

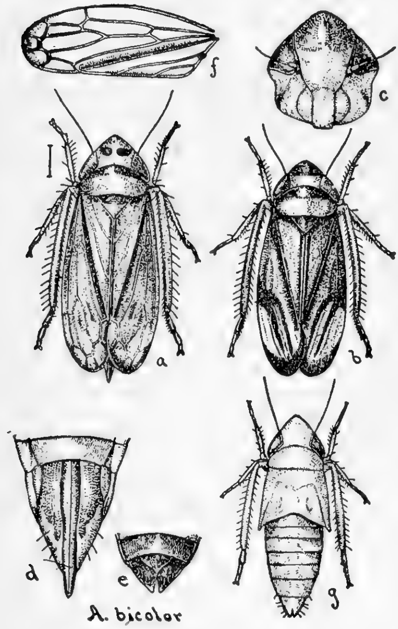

FIG. 23.—*Athysanus bicolor: a.* Adult female; *b,* adult male; *c,* face; *d,* female genitalia; *e,* male genitalia; *f,* elytron; *g,* nymph. All enlarged. (After Osborn and Ball.)

In color the females are yellowish green, with two large coalescent spots on the vertex, both margins of the pronotum, the entire claval suture, and the tip of the wing black; below, all light. The males have the whole point of the vertex, the sutural margin, and an oblique band from the anal cell to the center of the costal margin black. Below, all is black except a band across the middle of the face. This species can be readily separated from *curtisii* by the absence of the Y on the face and the fact that the yellowish-green of the elytra is not confined to the nerves. (See fig. 23.)

The nymphs are very light yellow, sometimes almost white, and the hairs are much smaller and finer than those of *curtisii,* which otherwise they closely resemble. They were first taken June 16, when the first adults of a brood were issuing, nymphs remaining abundant until the end of the month. The adults were very abundant until well

into July, disappearing before the end of the month, and appearing again toward the end of August and through September. There is nothing to be added in regard to the treatment for this species in addition to what can be recommended for the other species. Attention to the grasses in which it primarily breeds is evidently the most important consideration so far as present knowledge serves to indicate measures of control.

Athysanus obtutus Van D.

Athysanus obtutus Van D. (fig. 24) is another species with a very wide range, especially to the south and southwest, being known to

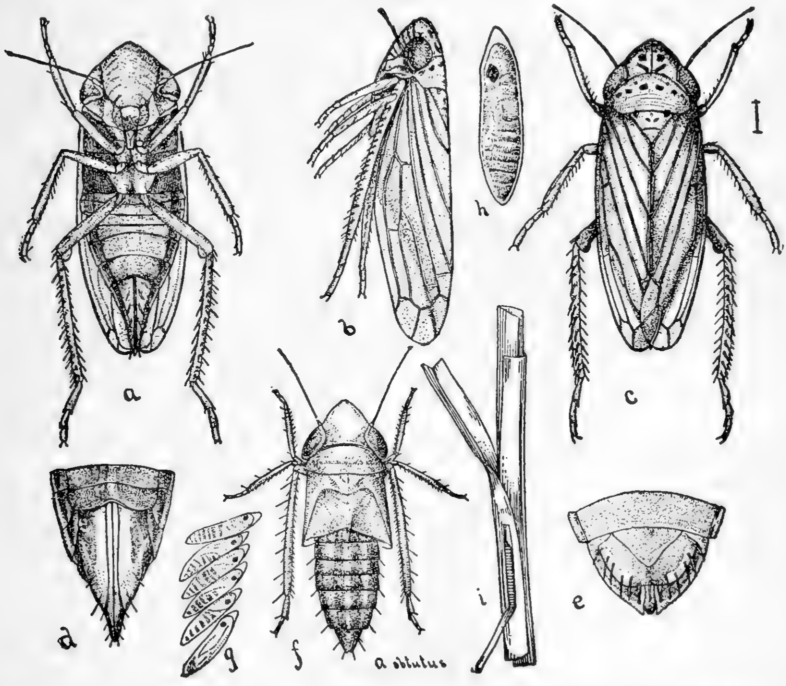

FIG. 24.—*Athysanus obtutus: a*, Adult from beneath; *b*, from side; *c*, dorsal view; *d*, female genitalia; *e* male genitalia; *f*, nymph; *g*, eggs; *h*, egg, more enlarged; *i*, eggs in grass stem, natural size. All but *i* enlarged. (After Osborn and Ball.)

occur all the way from Iowa to Central America, and from Washington, D. C., into South Carolina, Georgia, and other Gulf States.

The adults are very similar to *bicolor* in size and form, but differ distinctly in color, which is a pronounced chocolate-brown. The vertex is lemon-yellow, with two large brown spots just before the middle, and two small oblique dashes near the base darker. The apical cells of the elytra are nearly transparent, but the apical veins are distinctly blackish. The last ventral segment of the female is about the same length as the preceding segment, nearly straight or slightly concave on the hind border. The male valve is triangular; the apex is

distinctly angled and the plates short, rounded at the tips, and margined with strong bristles, the length a little over one-eighth inch. (See fig. 24, *a–e*.)

The eggs (fig. 24, *g*, *h*, *i*), which are deposited under the leaf sheath next to the stem of the plant, are elongate and slightly curved, a little thicker at the head end, which can usually be distinguished by the presence of the dark pigment of the eye spots. The nymphs (fig. 24, *f*) resemble the adults in form, but are of a light-yellow color when small, gradually becoming darker, and retaining about the same shade of brown in the last nymphal stage or pupa as prevails in the adult. The abdomen is distinctly narrower than the thorax, and the wing-pads of the later nymphal stages extend back over its base. The life history was followed at Ames, Iowa, adults being taken the last week in April, which would indicate an adult hibernation, and the first nymphs noticed in spring occurred in May and matured by the middle of June. Adults then occurred through June and the greater part of July, and full-grown nymphs, belonging evidently to the second generation, were found in the latter part of July and again before the middle of September, and adults occurred commonly throughout the remainder of the season. It would appear, therefore, that there are three broods during the season, the third one hibernating as adults, though the nymphs found in July may have been belated ones of the first brood. The food plant was determined to be *Andropogon scoparius* at Ames, Iowa, and it undoubtedly occurs on this plant as a regular thing, but adults at least have been very commonly taken on other plants. I found it in considerable numbers in wheat fields at Arlington, Va., College Park, Md., Columbia, S. C., and also fairly abundant on Bermuda grass at several points in the Southern States, especially Columbia and Clemson College, S. C. The occurrences in wheat were not so common as to indicate a very serious infestation to this crop, and unless eggs are laid in wheat in the spring the species is not likely to cause very serious damage to this crop. Very likely the adults simply migrate into wheat fields for the sake of better forage during autumn and return for the deposition of eggs to the grasses which are the ordinary food plants of the nymphal stages. The hibernating adults would be affected by burning, and this, with the use of hopperdozer or spraying, is about the only measure that can be recommended with our present knowledge of the habits of this species.

The Irrorate Leafhopper.

(*Phlepsius irroratus* Say.)

Phlepsius irroratus Say is one of the most abundant and widely distributed species of the genus, occurring all over the eastern United States from the extreme north to the Gulf and westward to the

Rocky Mountains. It is dark brown, the surface minutely irrorate on the vertex and pronotum, and with numerous fine reticulations or irrorations on the wings. (See fig. 25.) It is nearly one-half inch in length.

The life cycle of the species is not known in detail, but the nymphs occur quite commonly in grassland, meadows, pastures, and sometimes in wheat fields during the latter part of the summer. They are rather flattened and are more or less distinctly irrorate, with minute patches on the head, pronotum, and abdomen. Figure 25, *f*, represents a nymph taken at Toledo, Ohio, associated with the adults, and where other species were not present, so that there can be little doubt as to its being the nymph of this species. Such nymphs have been taken in many cases associated with adults of *irroratus* where

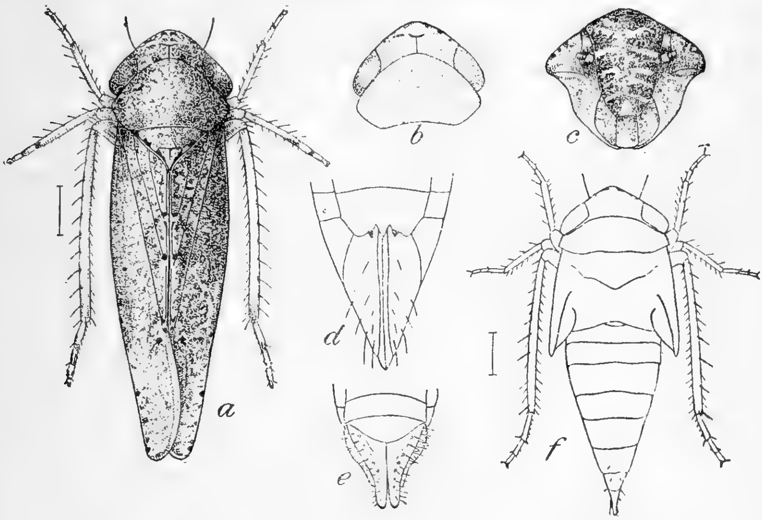

FIG. 25.—The irrorate leafhopper (*Phlepsius irroratus*): *a*, Adult; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, nymph from specimen taken at Toledo, Ohio. All enlarged. (Original.)

the species is abundant and at widely separated localities, so that there is practically no doubt as to its identity, although no rearing of the nymph has been made.

While the species is abundant throughout the Eastern and Central States and indeed throughout its entire range, its economic importance is not fully recognized since it occurs in quite general distribution and has never been recorded as swarming in any one particular place. It is hardly possible to collect leafhoppers in any part of the country, especially during late summer and autumn, without finding an abundance of this species, and it is certain that they must cause some injury in the crops which they affect. As mentioned on a preceding page, it was observed by Herbert T. Osborn swarming toward evening around trees at Urbana, Ill., in the autumn of 1909. It is

found especially in wheat fields, in clover, and grass, and has evidently a rather wide range of food.

Since it is so generally distributed, it is not such a simple matter to control it, but to some extent it could doubtless be controlled by the burning of the strips of grassland adjacent to fences, and especially in the South this should serve as a considerable relief from its attacks on winter wheat.

The Geminate Leafhopper.

(*Thamnotettix geminatus* Van D.)

The geminate leafhopper (*Thamnotettix geminatus* Van D.) has been recognized as of wide distribution, but hitherto has not figured in economic literature. It appears, however, that it must be taken into account hereafter since it has occurred in such numbers upon clover, alfalfa, and timothy in the State of Washington, especially at Pullman, as to threaten to become destructive. It was first described from California and later recorded for Colorado (Dolores, C. P. Gillette), both these localities being cited by Van Duzee in his catalogue.

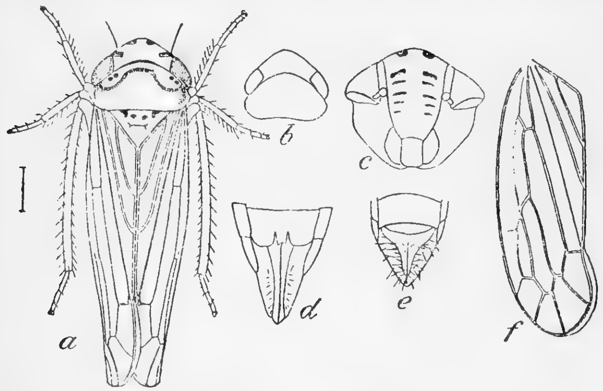

Fig. 26.—The geminate leafhopper (*Thamnotettix geminatus*): *a*, Adult; *b*, vertex and pronotum of male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, elytron. All enlarged. (Original.)

Under the name *Cicadula læta* it was recorded from Alaska and Shumagin and Popoff Islands by Ashmead in his report on the Homoptera of the Harriman expedition of 1898. Specimens under this same name also are in the National Museum from Ungava Bay, Territory of Ungava. The species is therefore of wide range and should it readily adapt itself to cultivated crops might easily become a serious pest. So far, and except for the California localities, it appears to have been restricted to the northern regions or to higher altitudes of the plateau region.

It is of a clear greenish-yellow color, the head having a pair of conspicuous black spots on the anterior border, another each side next the eye, and a conspicuous arched band near the front border of the pronotum. (See fig. 26.) The length is from 5 to 6 mm. The life history has not been traced.

The native food plant of the species is not known to me, but from its apparently ready adaptation to clover and alfalfa one would sus-

pect that it occurred primarily on some of the indigenous legumes of its original habitat.

The Six-spotted Leafhopper.

(*Cicadula 6-notata* Fall.)

The widely spread six-spotted leafhopper (*Cicadula 6-notata* Fall.) was described in Europe more than a century ago, and the references in systematic literature by Curtis, Flor, Germar, Kirschbaum, Fieber, Marsh, Melichar, and others show it to have been a common and well-known, and apparently a widely dispersed species in that country during the past century. Little seems to have been done with it from an economic standpoint. Leonardi, in the Italian work on Injurious Insects in Italy (Gli Insetti Nocivi), makes mention of it as an enemy of cereals but with no discussion of habits or modes of treatment. Edwards in a systematic work on British Homoptera records it as "very abundant on grasses." Doubtless many other such records occur scattered through the European works on insects, but a thorough discussion of the species for economic purposes seems never to have been given. Considering the present distribution of the species over the whole United States, including Alaska, its history in this country becomes a matter of great interest.

The first published record of occurrence of the species in America appears to be that of Forbes in 1884, followed by Woodworth (1885) and Provancher (1890), and there is a record in the Bureau of Entomology for Lafayette, Ind., by Prof. F. M. Webster, dated November 30, 1885.

Unfortunately we can not safely assume that lack of record by earlier entomologists is in this case any positive proof that the species was not present. While Say, Harris, Fitch, and Uhler all gave attention to this group of insects, and their studies together run back to 1820, they naturally could not be expected to recognize all that might have occurred, even in their respective localities. However, absence of records, especially in the case of such good collectors and acute observers, is in some degree presumptive evidence of nonoccurrence in the case of a species so abundant as this, and if we assume an introduction of the species at some period closely prior to its first notice we must recognize a rapid spread over the whole country, as it is stated by Van Duzee in 1894 to "occupy North America from Ontario and Connecticut to Alaska and California and south to Mississippi." There is in the records concerning the species in this country no sequence of dates which furnishes us any basis for tracing any dispersal from some center of introduction, as records for such

widely separated points as Illinois, Iowa, Ontario, Washington, D. C., California, and Tennessee appear all within five years of its first notice.

In this connection the unpublished records of the Illinois State entomologist, which were kindly placed at my disposal by Prof. Forbes, are of special interest. These records show the species to have been taken from wheat, oats, or grains, etc., in Illinois at the following places: Carmi, October 6, 1882; Cuba, May 15, 1883; Decatur, May 23, 1883; Bloomington, May 24, 1883; Normal, May 28, 1883; "S. Ill.," August, 1883; Centralia, August 7, 1883; Cherry Valley, August 17, 1883; and at West Union, Mt. Carmel and Marshall in May, 1884. This would show the species to be distributed over the entire State and to be well established, as in many cases the specimens in the collection are in large numbers and indicate an abundance in the field. The published record, moreover, speaks of them as in destructive numbers.

I took it in great numbers in Washington, D. C., in July, 1890,[1] and it appears in my list of Iowa species of Jassidæ in 1892.

In the Hemiptera of Colorado (1895) the species is recorded from Colorado Springs, August 1, and Fort Collins, July 24.

The National Museum shows a single specimen labelled "C. Mo. June" without date, evidently from the old Riley collection and probably collected before 1880; specimens from Los Angeles County, Cal., collected by D. W. Coquillett, which must have been taken between the years 1886 and 1893; others by Koebele, Sacramento and Placer Counties, Cal., certainly since 1880; one from San Francisco, Cal., June 24, 1885; one from Massachusetts, no date, but evidently a recent specimen, and another from Cimarron, Kans., 1891.

Bureau records or specimens show it to have been taken within the last five years at Clemson College and Spartanburg, S. C.; Hamilton, Ala.; Dallas and Denison, Tex.; Mansfield, Ark.; Mesilla Park and Springer, N. Mex.; Wellington and Manhattan, Kans.; Kingfisher, Okla.; and Tower City, N. Dak.

In March, 1909, Mr. Harper Dean reported as follows:

> Denison, Tex., March 22, 1909, drove 4 miles from town to farm of Mrs. Della Cramer, whose small field of barley, about one-fifth acre, had been killed outright, a week or ten days previously, supposedly by Toxoptera. No sign of the latter could be found, but there was an abundance of Jassidæ, all of one species. She said these were the prevalent insects at the time of the outbreak. Took a number of specimens and determined them by Dallas collection as *Cicadula 6-notata* Fall. Gave Mr. Tucker some of these specimens, brought remainder to San Antonio. The latter were so mutilated en route that only a single specimen was good. Sent this to Prof. Webster.

I found it generally distributed for the season of 1909, northwest to Washington State and southeast to South Carolina and Georgia.

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[1] See Insect Life, vol. 4, p. 197.

In the Dakotas it was usually the most abundant species in fields of wheat, oats, and barley, as well as the most universally present, but it was not in such numbers as to be counted destructive. At Dickinson, N. Dak., it was found on millet as well as on wheat and oats. It occurred at Mammoth Hot Springs, Yellowstone Park, in a small patch of cultivated grass; at Bozeman, Mont., on wheat, oats, barley, and timothy; at Missoula, Mont., on tame grasses; at Pullman,Wash., on Festuca; at Kalispell, Mont., and Williston, N. Dak., on wheat, oats, alfalfa, clover, millet, and brome grass; at Castalia, Ohio, August 13, in volunteer wheat; at Toledo, Ohio, August 13, in Hungarian grass; at Valencia, Harrisburg, and Reading, Pa., in wheat or grass; at Arlington, Va., November 12; at Raleigh, N. C., November 15; at Columbia, S. C., November 16; at Clemson College, S. C., in wheat, rye, and barley, November 17; at Knoxville, Tenn., in barley, November 22. All these records represent adult stages, and adults have been observed every month from March and June to November.

The life history of the species has never been given in detail, though brief statements concerning the nymphal period appear in some cases. Leonardi barely mentions "larva and nimfe" in connection with reference to the species as a pest to cereals. Some work was done on the life history at Ames, Iowa, years ago, but no publication was made, as it was hoped to complete lacking details.

There is little separation into distinct broods, and adults, as shown by records above, are to be found throughout the season, probably because of the short period of development of the young. In Texas adults, as shown in reports above, were abundant March 22. Webster gives a record of adults, confined on wheat kept indoors, which deposited eggs on November 11, the latter hatching November 27; and a further note on the last-stage nymph, December 24, would indicate the passing nearly to adult stage within a period of about six weeks, with indoor conditions. With present data, it seems impossible to determine definitely the number of generations during a season.

The adult insect is of a light greenish-yellow color, the head marked very distinctly with black dots or spots arranged in pairs, two round spots on the hind part of the vertex, a pair of transverse spots a little in front of the middle, and another pair, also transverse, at the border between vertex and front. The front is marked with black curved lines, and the sutures are black. The elytra are nearly transparent, the veins showing as lighter lines near the base and darker lines toward the apex, which also is somewhat smoky. The body above is black, the border of the abdomen yellow beneath, the body yellow, with black for the central part of the thorax and the basal portion of the abdomen.

The last ventral segment in the female is yellow, slightly longer than the preceding segment and slightly convex on the hind border. The pygofer is yellow; the ovipositor is black and equals the pygofer in length. In the male the last two ventral segments are whitish, somewhat hairy; the valve short, slightly angular; the plates nearly triangular; tips acute, scarcely reaching the end of the pyfoger. The length is about 3.5 to 4 mm. (See fig. 27.)

The nymphs are pretty easily distinguished by the markings on the head, which are very similar to those of the adult. The color is

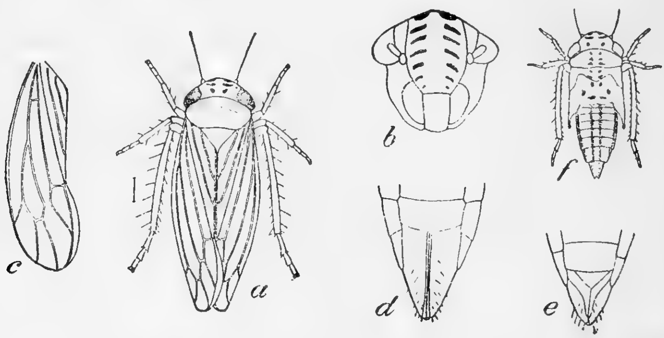

FIG. 27.—The six-spotted leafhopper (*Cicadula 6-notata*): *a*, Adult; *b* face; *c*, wing; *d*, female genitalia; *e*, male genitalia; *f*, nymph. All enlarged. (Original.)

usually a darker green, the head is more rounded, and the abdomen is slender. A separation into the different molts has not been secured.

The adults fly readily and probably to considerable distances, and at least two records, one in Kentucky and the other in Tennessee, show it to be attracted to light.

The ready migration may lessen the efficiency of rotation and clean culture, yet it was noticeable that very few were to be found in fields where recent planting or clean culture were the rule. The hopper-dozer methods would probably serve well in places where they can be applied.

EMPOASCA MALI Le Baron.

Empoasca mali was first described by Le Baron as a pest to the apple, and it has received considerable attention at various times in this connection and as a pest to various woody plants. It is also at times very destructive to other crops, having been noted on potatoes (Osborn), beans (Gillette), soy beans, cowpeas, alfalfa, clover, etc.

The insect is about 3 mm. in length, of a light grass-green color, usually quite brilliant and sometimes iridescent, this color prevailing throughout the entire body, but there is a series of whitish spots along the front margin of the prothorax, usually six in number, and

two whitish lines or stripes on the mesothorax which unite near the center by a transverse band, forming the letter "H." A small triangular white spot occurs on the scutellum with a small dot on either side. The eyes are brilliant white when the insect is alive, but turn to a dull brown in dried specimens.

The species, according to recent studies, appears to have three or four generations each year, and to pass the winter either in the adult or egg stage, a diversity of habit and life cycle which would seem to indicate its derivation from some other geographical region, or an adaptation to varied food plants furnishing it supplies of nutrition throughout the year. Such a diversity renders it more difficult to apply direct measures of control. Upon soy beans it occurs in the nymphal form during August and early September, and mature individuals are abundant in September and October which may deposit eggs, or very likely secrete themselves for hibernation during the following winter. A number of recent records show its occurrence on alfalfa and cowpeas, and in some instances I have noticed considerable injury to these crops as the evident result of its occurrence.

There are a number of reports of its injuries to forage crops and a few of these may be cited as example of the character of its work. At Clemson College, S. C., July 15, 1908, Mr. G. G. Ainslie reported that at the experiment station he found a lot of soy beans affected with a green leafhopper. He says: "They were present in great numbers in all stages, and many of the leaves were corrugated and curled by them. The lower leaves are yellowish. When the beans are disturbed, the hoppers fly out in clouds." The specimens collected and preserved in alcohol were identified as this species.

At Lexington, Ky., Prof. Garman records extensive injury to alfalfa, and notes a variety of food plants and that the insects migrate during the season, seeking fresh growth and succulent plants. He says that there are several generations. It occurs on clover and alfalfa in June and July and again in September. It is also destructive to cowpeas, and another record gives it as occurring on red clover.

At Lafayette, Ind., I found it common on soy beans and alfalfa October 5, and Mr. Phillips informed me that it was common and abundant on soy beans earlier in the season, and he attributed injury to the crop to its presence. As most of the varieties of the soy beans had ripened at the time of my visit I saw the insects on only one variety of soy bean but found them as both nymphs and adults, which would show that they develop on this plant. On alfalfa they were much more plentiful and included nymphs of different stages as well as adults. More recently, during the summer of 1911, Prof. Webster reported to me a serious infestation on the farm of Dr. H. W. Wiley, near Bluemont, Va., where the plants were entirely destroyed above ground.

The species was reported from Sharonville, Ohio, by Mr. L. E. Shepherd, June 17, 1910, with the statement that "it attacked second crop of alfalfa and it is turning yellow from the effect."

These various records show a ready adaptability to the alfalfa, and indicate that the species must be reckoned with in the growing of this crop.

THE NYMPHAL STAGES.

The nymphs are light green, often with a yellowish tinge, and are found usually upon the underside of the leaves of the plants which they infest, clustered commonly beside the midribs and main ribs of the leaf, where they suck the juices of the leaf.

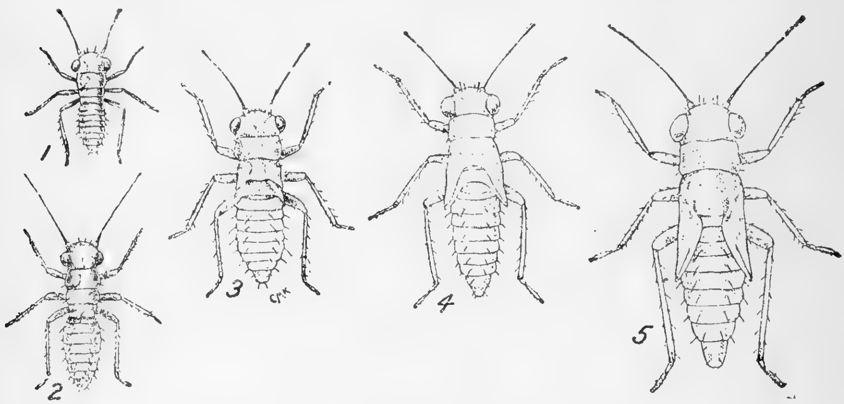

FIG. 28.—*Empoasca mali:* Five nymphal stages. All enlarged. (After R. L. Webster.)

The stages (see fig. 28) are described by Mr. R. L. Webster, as follows:

Stage I.

Length 1 mm. (average of 10 specimens).

Head, thorax, abdomen, and legs pale when first born. After the young hopper has taken some food into the body, the abdomen takes on a yellow color. The eyes are dull reddish. Two rows of six spines are on either side of the meson; one dorso-laterad, one ventro-laterad, in position; one spine in a row to the segment. Spines small, pale. Caudal border of metathorax blunt in outline.

Stage II.

Length 1.26 mm. (average of 10 specimens).

Head, thorax, abdomen, and legs pale green; eyes dull reddish, antenna, segments I and II pale, remainder dusky. Caudal border of metathorax sharp in outline.

Stage III.

Length 1.56 mm. (average of 10 specimens).

General color pale yellow, orange on dorsum of abdomen. Eyes dull reddish. The wing pads now appear quite distinctly and reach to the caudal border of the first abdominal segment.

Stage IV.

Length 1.86 mm. (average of 10 specimens).

Head and thorax pale; abdomen pale yellow; eyes dull brownish. The wing pads now extend to the caudal extremity of the second abdominal segment.

Stage V.

Length 2.26 mm. (average of 10 specimens).

This stage is rather broader than IV. Head, thorax, and wing pads pale green; abdomen dull yellow; eyes dull brownish. The wing pads extend nearly to the caudal border of the fourth abdominal segment. Antenna; I and II pale green, remainder dusky.

DISTRIBUTION.

The species is universally distributed over a considerable part of the United States. Records of collection have been made for practically all the points at which collecting has been done in the Mississippi Valley and Atlantic slope regions.

TREATMENT.

The control of the insect is rendered more difficult because of the large variety of plants upon which it may feed, and its ready migration from one to the other. Upon potatoes, alfalfa, and other low-growing crops the use of kerosene spray is perhaps the most available direct treatment, but for large areas this is a rather expensive process. Moreover, its most successful application is limited to times when the crop is young or short enough so that the spray may reach the foliage thoroughly. The treatment of apple trees or nursery rows, where it is often especially injurious, must be accomplished by the use of especially devised hopperdozers or shields carried along the rows in such manner as to dislodge the hopper, or by the use of spraying machinery especially devised for this kind of application.

The Clover Leafhopper.

(*Agallia sanguinolenta* Prov.)

The clover leafhopper (*Agallia sanguinolenta* Prov.) (fig. 29) is one of the most abundant and widespread species of American jassids, but very little has been done in the matter of working out its habits and life history and that little within the last two decades. It was described by a Canadian entomologist, Abbé Provancher, in 1872 and later, 1876, was again described by Prof. Uhler and has been several times referred to in later papers under the name *Bythoscopus siccifolius* Uhler. Possibly some of the references to *novellus* Say included this form as it must have been an abundant species in earlier days. It was treated as a grass insect in 1890 in an article by the writer.[1] It was discussed, included, and figured as a sugar-beet insect by Prof. Bruner in a bulletin on sugar-beet insects in 1891 [2] under the name *Agallia siccifolia*, and in November of the same year the writer treated of and figured its various stages as a clover pest and also mentioned it [3] as a sugar-beet pest under the name now used. As this account gives substantially what is known concerning the life history and

[1] Bul. 22, o. s., Div. Ent., U. S. Dept. Agr., 1890.

[2] Bul. 16, Nebr. Agr. Exp. Sta., Apr., 1891.

[3] Bul. 15, Iowa Agr. Exp. Sta., 1891.

habits and as the bulletin is no longer available for distribution I quote directly from that article.

April 15th, we confined several in a breeding jar upon growing blue-grass. April 24th, they were observed copulating. April 26th, all were dead. Where they fed upon the blue-grass their punctures appeared as small white spots, the epidermis only remaining about the point from which they had sucked the nutritive juices of the blade.

April 27th, some specimens taken in copulation in the field were confined on growing clover. Their liking for the clover as compared with blue-grass was very apparent and we had no difficulty in carrying them forward on this food plant. They preferred to feed by inserting their beaks in the petioles, or stems, of the leaves, in which position they would remain motionless for hours at a time sucking out the juices of the plant. They would also sometimes feed upon the blade.

The wilting of the clover from their incessant drains upon it was evident and it was only by frequent and generous watering that it was kept growing. By the middle of May few specimens could be found outside of clover fields and sweepings made at intervals throughout the summer failed to disclose them elsewhere in sufficient numbers to attract much attention. During October they could again be found in blue-

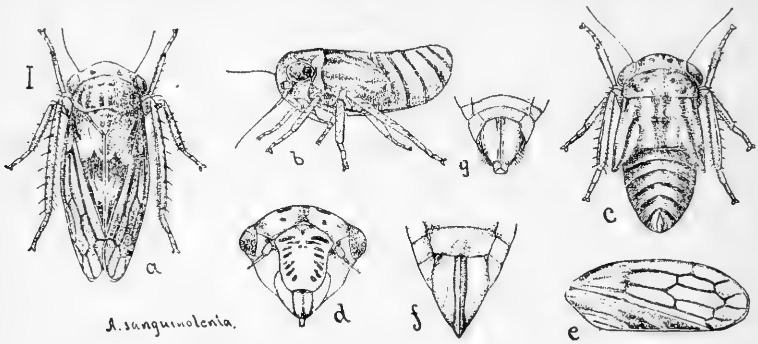

FIG. 29.—The clover leafhopper (*Agallia sanguinolenta*): *a*, Adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. All enlarged. (After Osborn and Ball.)

grass patches and about weedy spots to which they migrate on the approach of winter, or perhaps as soon as their favorite food plant begins to show the effects of cold weather.

From their numbers in this locality and their method of attack we should count them among our most serious clover insects.

The first larvæ were found in our breeding jars May 20th. They much resemble the adults except that they are smaller and nearly white in color. A few eggs were observed inserted beneath the epidermis along the midrib of the blade. Most of the eggs must have been laid elsewhere, however, probably among the bases of the petioles about the crown of the root, or beneath the epidermis on the petiole where they would not be easily discovered. June 9th, the wings of the older nymphs nearly covered the body and by the first of July they were mature. Hatching at this time was still in progress, so that we had every stage in the life-history of the insect represented at the same time in our cages. Nymphs in all stages were found from this date until late autumn, the new adults doubtless beginning egg-laying in July, or August, and the larvæ of the first brood would be maturing all through the months of July, August, and possibly September. The earliest adults of the second brood might have time to oviposit and produce a third brood in autumn, some specimens of which could mature, but we have no doubt that the great majority of the insects are included in two broods. This conclusion seems probable to us from the rate of growth, and the fact that few nymphs are to be seen late in fall. We have found none in spring and think that the belated ones of fall perish during the winter.

Distribution is general from New England through southern Canada, Washington, and Oregon and south to Georgia, Mississippi, and Vera Cruz, Mexico, and west to Arizona and California.

It affects a wide range of crops, as might be inferred from mention already made, but it shows a preference apparently for clover, alfalfa, and other legumes and so far the nymphal stages have been taken almost exclusively on plants of this group. During the season of 1909 it was observed in stubble with grass and clover at Grand Forks, N. Dak. July 28. It was found at different points in Ohio in August and September—at Cedar Point during August; at Wooster during September, in stubble-fields, including clover. At Lafayette, Ind., on October 5, it was found on alfalfa; at Harrisburg, Pa., November 5; at Reading, Pa., on November 6, in pasture and in wheat; at College Park, Md., on November 11, in grass strip next to wheat; at Arlington, Va., on November 12, in wheat plat; at Washington, D. C., on November 13, in leaves (?); at Raleigh, N. C., on November 15; at Columbia, S. C., on November 16, in wheat; at Knoxville, Tenn., on November 22, on alfalfa and red clover; at Maysville, Ky., on December 4, in wheat, near border of field. While not in excessive numbers in any of these localities it was often abundant enough to be considered as a distinct drain on the crop. In every case where it was observed in wheat fields it was in the adult stage and had very certainly migrated thither from adjacent pastures and meadows. Probably in none of these was clover entirely wanting, and I believe we may safely base measures for avoiding injury to wheat or other fall-planted crops on the assumption that it comes from near-by meadows or pastures that have been a year or two at least in grass and clover. As for the injury in clover fields or alfalfa, I believe this to be very considerable not only in checked growth but very probably in lessened seed production from its attacks on the blossoms and newly forming seed. Herbert T. Osborn, of the Bureau of Entomology, reported it as abundant and apparently the most injurious jassid in alfalfa at Wellington, Kans., in the winter and spring of 1910.

This species is closely related to the *Agallia venosa* Fall., of Europe, which, according to Edwards, is "very common at the roots of grass, etc." This would indicate a similarity of habit and possible derivation from a common ancestral form.

The adaptation in our species to clover and alfalfa, which are both introduced plants, may therefore have been an easy matter since it probably fed upon some native legume before these plants were available. The increasing abundance of the species on adaptation to a new food plant simply follows a very general law with reference to the adaptation of native insects to introduced crops. Considering the present distribution of the species, and especially in its relation to other species of the genus, it seems probable that it has migrated from

a southwestern habitat since introduction of its host plants. Such a history would accord well with the fact that no mention of the species was made by Say or other writers during the first three-fourths of the nineteenth century. It seems hardly possible that it could have escaped them if it had occurred in its present abundance and wide distribution. In whichever direction it may have been dispersed it seems quite certain to have been in connection with cultivated crops, as it does not occur in the uncultivated areas to which some of its congeners seem well adapted. A similar tendency to adopt alfalfa and clover is, I believe, manifested by *Agallia uhleri*, which recently has been taken in abundance on these crops by Mr. C. N. Ainslie at Mesilla Park, N. Mex.

TREATMENT.

Owing to the habit of adult hibernation, the winter or early spring burning of rubbish and dead leaves where they occur is likely to be quite effectual in their reduction and where they occur in destructive abundance the spraying of alfalfa or clover fields directly after cutting a crop should be of distinct advantage.

The species has been noticed to harbor considerable numbers of minute hymenopterous parasites, probably of the genera Dryinus or Gonatopus, and it is very likely that these parasites assist in keeping their numbers within such bounds as to prevent very notable injuries.

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